THE DEVELOPMENT OF AN EFFECTIVE LEARNING ENVIRONMENT IN HIGHER EDUCATION FOR PRODUCT DESIGN

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This work or any part thereof has not previously been presented in any form to the University or to any other body whether for the purposes of assessment, publication or for any other purposes (unless previously indicated). Save for any express acknowledgements, references and / or bibliographies cited in the work, I confirm that the intellectual content of the work is the result of my own efforts and of no other person.

Signature......A. J. Felton..........

Date......27TH Feb 2001......

Abstract

This thesis is concerned with the development of an effective learning environment in higher education for product design.

The research and development undertaken focuses predominantly on the BSc (Hons) course in Computer Aided Product Design (BSc CAPD) at the University of Wolverhampton, in the UK. Conceived in 1989 as a collaborative venture between the School of Engineering and the School of Art and Design, it was in the vanguard of a new wave of product design initiatives in the higher education sector that had a multidisciplinary approach. It was one of the first degrees within the institution to adopt an integrated approach, integrating engineering design from the former with industrial design from the latter, developing a mixture of technical and design skills using the computer. It aims at developing an employable graduate designer with a richer blend of skills and possessing a greater awareness of the relationship between Design and Manufacture in the specialist field of Computer Aided Product Design.

The research documents the growth of Product Design courses in the UK over this period of time and a comparison is made of the BSc CAPD course with the Industrial Design Engineering degree at the Technical University of Delft in Holland, considered exemplary in its field.

The thesis reviews BSc CAPD's integrated approach over the first decade in terms of providing an effective learning environment for product design and achieving the aims and objectives of the course, as set out in Chapter 2 (2.3.2.1 Aims) and (2.3.2.2 Course Objectives). The effective learning environment in product design is achieved and documented in the thesis as follows: -

- The integration of engineering and art and design staff to deliver the curriculum.

- Education linked to Product Design, the project base, especially live projects, in providing the vehicle to BSc CAPD's integrated approach to curriculum development, teaching and learning.
- Integration of computers into the design curriculum.
- Technology supported learning in product design. The evaluation of Video Conferencing in a distance learning environment and the development of a Computer Assisted Learning (CAL) package / tutor system for teaching 2D CAD.
- Creativity / Innovation in Product Design.
- Industrial needs for designers (Designer's Skills). Developing a student's taxonomy of Design skills (Designer's checklist of skills).

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The author dedicates this work to his dear wife, Pauline and his daughter Rachel for their continued support over the years this research has taken place.

"All that we do, almost all the time,
is design, for design is basic to all
human activity".

Victor Papanek

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Glossary of Acronyms and Terminology

ADAR. Art and Design Admissions Registry.
A Level. Advanced Level.

BA/BA(Hons). Bachelor of Arts/with Honours.
Baccalaurens. (Dutch) Graduates with an HBO degree use the title of *baccalaurens,* often abbreviated to *bc.* HBO graduates also have the right to use the international title of Bachelor.
Black Country Access Federation. Local franchised colleges offering Access courses to Higher Education.
BSc/BSc(Hons). Bachelor of Science/with Honours.
BTEC. Business and Technology Education Council.

CAD. Computer Aided Design.
CAE. Computer Aided Engineering.
CAL. Computer Aided Learning.
CAM. Computer Aided Manufacture.
CAPD. Computer Aided Product design.
CBL. Computer Based Learning.
Cert. Certificate.
CNC. Computer Numerical Control.
Co-Designing. Group of designers or students working together on group design projects. See also TPD.
Collaborative Engineering. The technique of sharing CAD data between centres using videoconferencing.
COMETT. Grants made available to promote and foster co-operation between industry and higher education within Europe.
Concurrent/Simultaneous/Parallel Engineering. Philosophy of developing a product with specialised teams. Specialised personnel attached to the product team i.e. concept designer, manufacture, marketing etc from the outset.
CPVE. Certificate of Pre-Vocational Education.

2 D. Two Dimensional.
3 D. Three Dimensional.
Dip. Diploma.
doctoraal. (Dutch) *A* degree programme usually four years of study at universities.
doctoraal scriptie. (Dutch) degree thesis based on the student's research project.
doctoraat abbreviated to (dr.) or ***promotie*** (Dutch) the highest possible academic achievement in the Netherlands. The Dutch doctorate is comparable to a Ph.D.
doctorandus. (Dutch) Graduates of a *doctoraal* programme may use the title *doctorandus,* which is abbreviated to *drs.* in front of the name. However in law and engineering the titles of *meester* (*mr.*) and *ingenieur* (*ir.*) are used respectively. The introduction of the University Education Act of 1986 has made it possible for *doctoraal* graduates to use the international title of 'Master ', abbreviated with an 'M' after their name.

ERASMUS. Provision of mobility grants for European higher education student exchange programmes.

FE. Finite Element Analysis: to determine the stress or deflection of a product/component.
FMEA. Failure Mode and Effect Analysis.
Form-giving. Is translated from the Dutch word **Vormgeven** meaning to give shape/form.

GCSE. General Certificate of Secondary Education.
GNVQ. General National Vocational Qualification.
GPRS. General Packet Radio Service: method of handling data over digital mobile phone, where the phone is connected to the network constantly, allowing immediate email, web connections.

HAVO. Dutch) Senior General Secondary Education.
HBO. Dutch) (HBO = *hoger beroepsonderwijs*) Higher professional education that is offered at Polytechnics and Colleges (*hogescholen*)
HE. Higher Education.
HNC. Higher National Certificate.
HND. Higher National Diploma.
Hogescholen. (Dutch) Polytechnic or College.

IED. Institute of Design Engineers.
I.D.E. Industrial Design Engineering.
IDEATE. (IDEATE is a word TU Delt invented from a combination of Idea and Create. It is used to describe a research group and its activities. The research is centred on supportive tools, methods and techniques that support designers in the early form-creation phases of the design process. In this context, the ability to create form and express ideas is of utmost importance hence the 'play' on the two key words.)
***Ingenieur*.** (Dutch) graduates with an HBO degree in agriculture and technology use this title abbreviated to *ing*.

JIT. Just-in-Time - Japanese working philosophy. The just-in-time production concept was developed in Japan to eliminate waste of materials, machines, capital, manpower, and inventory throughout the manufacturing system.

Kanban. Using the JIT concept a Kanban, means visible record. These records usually consist of two types of cards (Kanbans). One is the production card, which authorises the production of one container of identical, specified parts at a workstation. The other card is the conveyance or move card, which authorises the transfer of one container of parts from that workstation to the workstation where the parts will be used. The cards contain information on the type of part, place of issue, part number, and the number of items in the container or cart, usually in the form of bar-coded plastic tags.
Kaizan. Japanese working philosophy, work improvement process on a continuous basis.

LBO. (Dutch) Junior Secondary Vocational education.
LEONARDO. See also **ERASMUS** above. Strand I. Supports the improvement of vocational training systems and arrangements in the European Member states. Strand II supports vocational initiatives that benefit companies and employees including University/enterprise co-operation. Strand III supports the development of language skills, knowledge and dissemination of innovation in vocational training.
Level 1. Equivalent to Year 1 of a full time BSc/BA course.

Level 2. Equivalent to Year 2 of a full time BSc/BA course.
Level 3. Equivalent to Year 3 of a full time BSc/BA course.
Level 4. Modules at 'Masters' awards.
LINGUA. Provision of mobility grants for European higher education Language student exchange programmes.
Live Projects. Design projects linked with industry (often sponsored).

MAVO. (Dutch) Junior General Secondary Education.
MBO. (Dutch) Senior Secondary Vocational Education.
meester. (Dutch) graduates with an HBO degree in Law use this title abbreviated to *mr.*
MSc. Master of Science.

O Level. Ordinary Level.
ONC. Ordinary National Certificate.
OND. Ordinary National Diploma.
Over the wall design. i.e. the designer who produces concept designs and then discharges the design to the production / manufacturing engineers to sort out and produce.

Parametric CAD. Dimension driven, variable geometry, CAD system.
PCAS. Polytechnics Central Admissions System.
PhD. Doctor of Philosophy.
post-doctoraal. (Dutch) advanced training and research programmes following the *doctoraal* degree including PhD.
Promotie. (Dutch) see also ***doctoraat*** *above.* The highest possible academic achievement in the Netherlands comparable to a Ph.D.
Propaedeuse. (Dutch) First year of a course usually at polytechnic or university.

Rapid Prototyping. Facilitates the direct and immediate generation of physical prototypes from 3D models, without the need for specific moulds or tooling.
Rendering. Shading/Colouring technique applied to enhance product designs/models. Hence hand rendering produced by hand, or computer generated rendering produced using computer software.

SAD. School of Art & Design.
SEBE. School of Engineering & the Built Environment.
SEED. Sharing Experience in Engineering Design. (UK based institution of Engineering Designers and the Engineering Design Lecturers organisation.
SOCRATES. Support (often grants/funding) provided for a wide range of activities to enhance European co-operation in the higher education sector. Usually linked via ERASMUS or LEONARDO.

Telematics. Word used in Netherlands to cover a range of information and communications technology (ICT) such as multi-media, Tele-learning, mobile communication, electronic commerce and the Internet.
TELL. (Dutch) Teacher-aiding Electronic Learning Unit. 'Philips' design for a learning unit.
Tentamens. (Dutch) Specified written and oral examination which students must pass.
TPD. Total Product Design. The integration of undergraduate engineering by getting students involved in real, open-ended, industrially based products. TPD is a team-based activity, students working in-groups of approximately five. See also Co-Designing.
TRIZ. Russian acronym for the theory of inventive problem study.

TU Delft. Delft University of Technology (Netherlands)

UCAS. Universities and Colleges Admissions System.
UCCA. Universities Central Council on Admissions.

VWO programme. (Dutch) a pre-university diploma offered by a secondary school.

WOLF. Wolverhampton On-Line Learning Framework.

Chapter 1

1. Introduction

In the first instance, the question to be asked is what is Product Design? [1]Faste (1999) gives the valid statement: - "Product design concerns itself with conceiving and designing products for the benefit of society. This process requires resolution of constraints from technical, aesthetic, human and business concerns. A product designer uses his or her creativity, imagination and technical knowledge to satisfy these requirements and create a product satisfying a human need".

Broadly speaking, the difference between product design and industrial design is that, in the past, industrial design has been more concerned with the aesthetics of products, rather than how it works or the technical aspects of the product. Traditionally the training in industrial design has involved a broad art education, mastering amongst other skills the art of product presentation utilising hand drawn rendering techniques. The product designer, however, is expected to design the product considering both its aesthetic appearance and functional efficiency and therefore needs a technical knowledge of an engineering nature as well as the ability to style creatively.

[2]The 'Training Designers for The 1990's conference report' (1983) carried the following paragraph, which had been reproduced and quoted from the Carter Report of (1977): -

"Industrial design and engineering design are at present distinct disciplines arising from different historic roots and different education systems. Each discipline has much to

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[1] FASTE, Rolf. (1999) *General Information about Product Design,* Product Design Program: General, Department of Mechanical Engineering , Stanford University, CA, USA. http://www-cdr.stanford.edu/DD/PD/intro.html p.p 1-3.

[2] CARTER Report (1977) a section of which was reprinted in the *Training Designers For The 1990's.* (23rd Nov 1983) Heads of Industrial Design Conference Report, Royal Institution London:The Design Council, p.8.

learn from the other; a process that can be advanced by the teaching of both side by side in polytechnics and colleges of higher education. In the long term it may be that a type of engineering designer will emerge who will be qualified to absorb some of the present functions of the industrial designer".

From its conception the BSc (Hons) course in Computer Aided Product Design (BSc CAPD) transcended these boundaries to produce a product design graduate who fits this last category i.e. someone with skills that could work across the design spectrum from industrial design to engineering design.

In dealing with the design process the following two models, Fig 1.1 Pugh's 'Total design activity model' and Fig 1.2 Pahl and Beitz's model 'Steps of the design process', are used by many authors and academics to explain the design process. Both models are similar in that they apply a systematic approach to the design process. This usually includes market need, product specification, concept design, preliminary design, detail design, manufacture and sell concluding with the retirement of the product.

[3]Hurst K (1999) makes the statement "A systematic approach permits a clear and logical record of the development of a design". Hurst proposes Pugh's Model of the design process as the model recommended by SEED (SEED, Sharing Experience in Engineering Design i.e. the UK based Institution of Engineering Designers and the Engineering Design Lecturer organisation).

Using Fig 1.1 Pugh's design activity model, the BSc CAPD course aims to develop a wide-ranging set of skills which covers the majority of the design activities shown in the model, thus giving the product design graduate currency for employment.

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[3] HURST, Kenneth, S. (1999) *Engineering Design Principles*. London: Arnold, p.8.

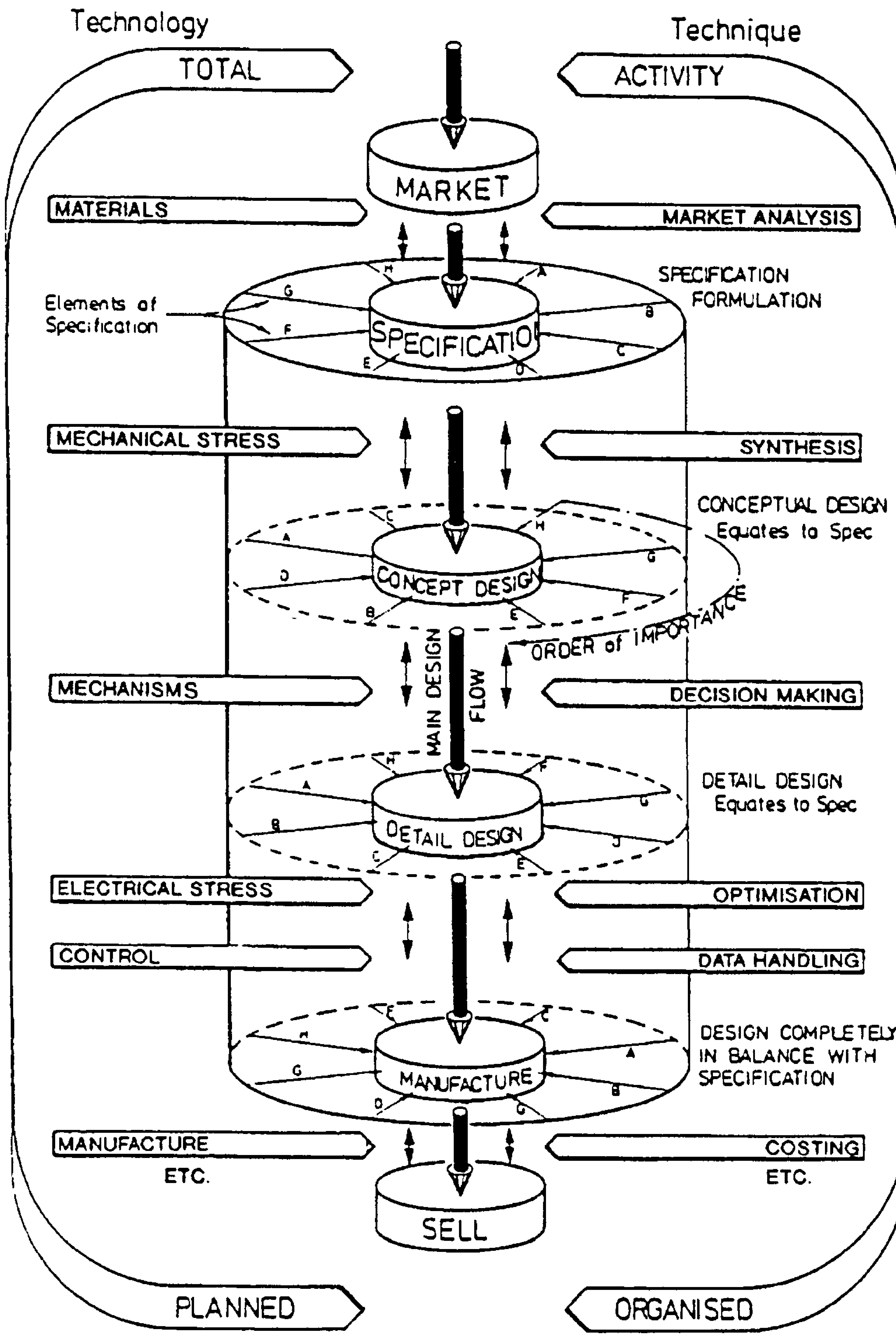

Fig 1.1 Pugh's 'Total design activity model' reproduced by kind permission of Addison-Wesley Publishers Ltd.

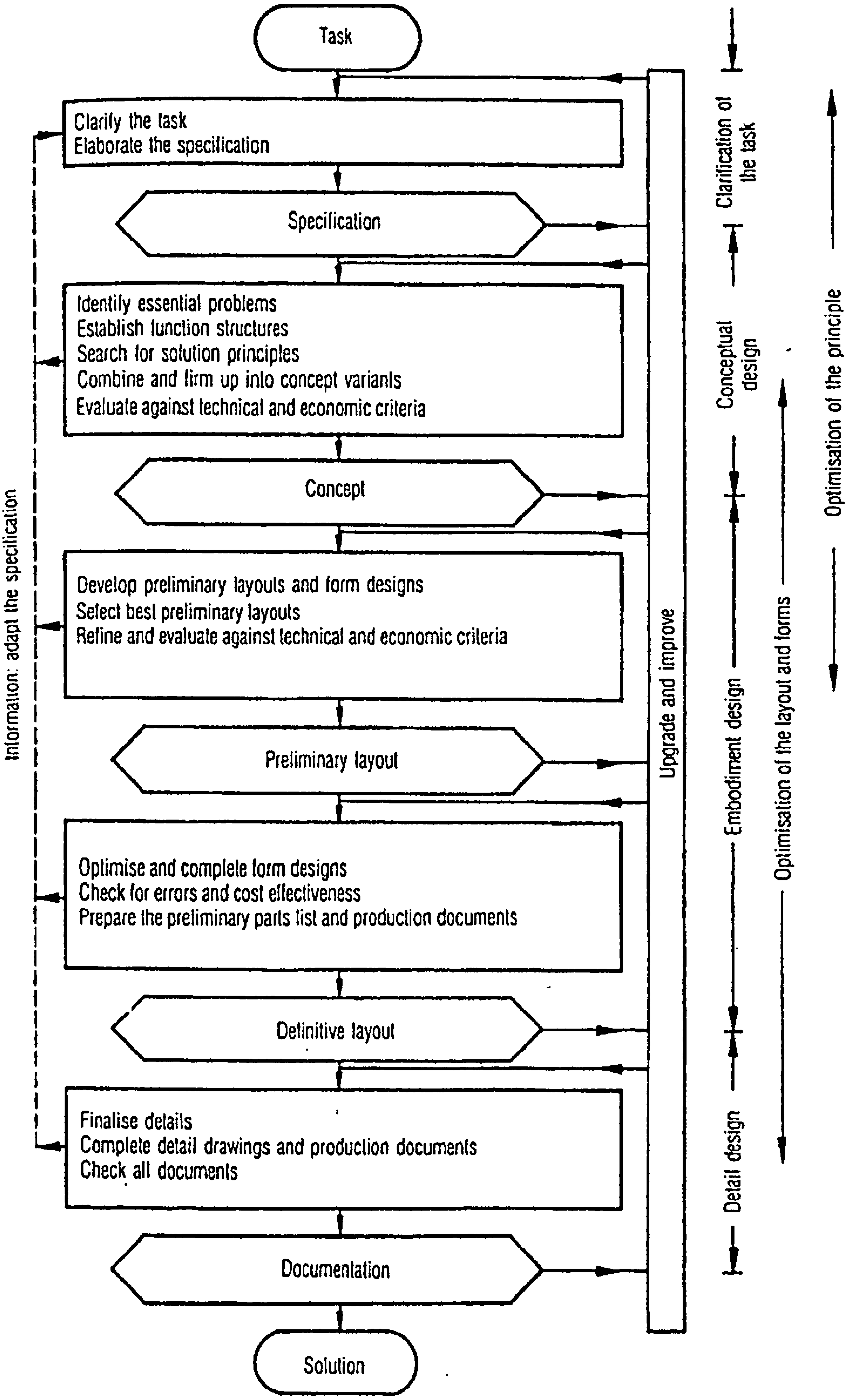

Fig 1.2 Pahl and Beitz's model 'Steps of the design process' reproduced by kind permission of the Design Council

The research proposal addresses rapid changes in the field of product design due to the increasing use of computer based technologies, both as a design tool and as a facilitator in the new learning environment.

The adoption of new methodologies to meet these concepts indicates the educational and industrial requirements for Product Designers to have broad perspectives and greater interactive viewpoints.

Skill levels and knowledge bases are changing, therefore the Academic world needs to recognise this and develop new teaching / learning strategies which promote and foster the culture of the 'integrative philosophy' to meet industrial requirements for Product Designers.

The original three main aims of the investigation are: -

1) An examination and evaluation of current courses, teaching approaches, and industrial requirements to establish the best practice in Product Design Education.
2) A translation of the best practice in curriculum design for future teaching methodologies.
3) An implementation and evaluation.

The following summary of the research undertaken will demonstrate that these three main aims have been achieved.

A literature review at the start of the research programme in September 1993 revealed that no other BSc or BA courses existed in the UK with the title 'Computer Aided Product Design'. Indeed, the BSc CAPD course from its conception in 1989 was in the vanguard of a new wave of product design courses in higher education. At the time a European course having similarities was the long established Industrial Design degree programme at the Technical University (TU) Delft in the Netherlands, which also had the integration of computers in product design as a main objective. Therefore, a collaborative relationship was established with the design department at TU Delft. Access to curriculum details and student numbers applying for the Industrial Design programme at TU Delft were obtained, allowing comparisons to be made between the BSc CAPD course at the University of Wolverhampton.

Over the period 1993/94 and 1999/2000 higher education courses in Product Design / Industrial Design were examined in the UK to establish the number of courses and student data on the number of places made available. From these findings, characteristics such as the growth in product design courses in the UK are documented in Chapter 2 and outcomes have been established.

The BSc CAPD course aims to produce an employable graduate with a broad range of transferable skills who can then enter a new and fast changing job market that does not offer a traditional career for life, but requires adaptability. It was one of the first close collaborative ventures within the institution between the School of Engineering and the School of Art and Design; the course has bought together design, engineering, manufacturing and computer skills. Integration has been the key word, the two schools offering the broad range of inter-related skills of: -

- Design Awareness and Visual Communication
- Product and Engineering Design
- Manufacturing and Technology
- Computing and Information Technology
- Business

The other integrating vehicles for these skills and curriculum development to promote and foster the 'integrative philosophy' have been the practical design projects that occur in each level (year) of the course and the group projects which build on team working skills. Increasingly, more 'Live' projects linked with industry have been introduced and national design competitions entered. These are documented in the thesis and provide the foundation in developing an effective learning environment in higher education for product design.

Much of the future teaching methodologies will revolve around Technology Supported Learning, including Computer Assisted Learning (CAL) or Computer Based Learning (CBL) and its delivery. As part of the research into this area, a section of Chapter 3 focuses on the use of desktop Video Conferencing in the Engineering Department at the University of Wolverhampton. The application of video conferencing for remote teaching on a Master of Science Degree with a Finnish institution is discussed, based on a case study. It highlights the successful transmission and usage of shared software applications between the engineering staff and students at the two institutions concerned, evaluates the potential for such applications and discusses the structure for possible future developments, including implementation in undergraduate courses and industrial-based projects.

The other major research area is in Technology supported learning. In Product Design this focused on developing a learning and teaching package for 2 Dimensional Computer Aided Design (2D CAD) under the 'Broadnet Project'. Its successful integration with commercial CAD software, its introduction into the engineering curriculum and the evaluation of the product is documented in Chapter 3.

Chapter 4 deals with the role of industry in meeting industrial needs. A survey was carried out with a range of product design companies on recruitment criteria for design engineers and product designers. The survey was based on a detailed questionnaire, designed also to establish what skill levels companies expect from prospective designers or skill levels they felt designers were lacking. The conclusions from this, and the successful development of the BSc CAPD curriculum, have allowed a student's taxonomy of Design skills to be produced (Chapter 6), in effect a designer's checklist of skills which is a model for the Concept, Industrial, Product and Analysis designer showing the skills distribution for each.

Due to the responses made by the companies in the areas of creative ability and innovation, and the vital role creativity plays within the design process, it was felt by the author that a chapter on this subject (Chapter 5) should be included in this thesis.

The literature review was continued during the course of the research programme, and some of the research outcomes have been published and presented at eight refereed conference proceedings by the author, where appropriate these are referenced in the thesis.

Chapter 2

2. Product Design – Educational Framework

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At the start of this research programme in late 1993 and early 1994, higher education courses in Product Design / Industrial Design in the UK were examined to determine the number of courses available and student data on applications for design courses. The BSc CAPD was one of the first computer aided product design courses in the country and, therefore, had the potential for growth both in student numbers and in curriculum development.

This process has since been repeated to cover product design courses available in the UK during 1999. A section of the chapter '2.2 Courses In Product Design UK' covers this particular area of research and shows the growth and variation in the number of product design courses now available to students.

In 1980 the Imperial College of Science and Technology and the Royal College of Art ran a unique joint postgraduate course for engineering graduates wishing to become industrial designers, which was the first of its kind in the UK. However, this was not the only course combining the Sciences and Arts, Engineering Design courses at Cranfield, Loughborough University and the University of Bath all ran courses with Industrial Design input. By 1985 Brunel University was starting a new undergraduate joint course in addition to other institutions including Huddersfield Polytechnic, Colchester Institute, South Bank Polytechnic and Lanchester Polytechnic (Coventry) with Industrial Design and Engineering Design inputs. However, there still remained barriers between Industrial design and Engineering design.

Preliminary research [Ref:- [1]British Councils Directorates in Western Europe (1993/94) and [2]Design Education in the Netherlands (1989)] indicated a small number of Universities in the Netherlands renowned for their design programmes, the principal institutions being the University of Twente and Delft University of Technology (TU Delft). Following visits made to Delft the Faculty of Industrial Design Engineering was identified as the leading exponent and exemplary in the field of industrial/product design breaking down the barriers between Industrial Design and Engineering Design and its' integration of computers in the design curriculum. The BSc CAPD course had similarities in this respect, in that integrating computers in product design had played a major role in its course development.

At the time, a departmental working relationship had been established by the head of engineering at the University of Wolverhampton and his equivalent at TU Delft through the ERASMUS partnership and student exchange programme; a letter of collaboration was obtained by the author between the two institutions based upon this part of the research activity.

The author made a number of visits to the Faculty of Industrial Design, TU Delft; two of these visits were to interview BSc CAPD students regarding the projects they had undertaken whilst on a one year exchange placement at Delft. The visits also gave the opportunity to see the facilities and to obtain information regarding student numbers on their design programme and details of the Dutch education system linked to Product

[1] BRITISH COUNCIL DIRECTORATES IN WESTERN EUROPE. (1993/94) *Listings of the British Council throughout Europe.* National Academic Regional Information Centre, British Council, Manchester, UK.

[2] *Design Education in the Netherlands.* (1989) The British Council, Keizersgracht 343, 1016 EH Amsterdam, Netherlands.

Design. The following section of the chapter '2.1 The Dutch Education System' deals with this aspect of research.

The main visit took place on the 16th-17th March 1994, following a successful application by the author for funding from 'The Royal Academy of Engineering, London' for an international travel grant. During the visit the author interviewed the head of school and other members of staff to establish course content, structure, curriculum development and research activities associated with their industrial design programme. Characteristics of the design programme have allowed comparisons to be made with the BSc CAPD course at the University of Wolverhampton. Possible areas were also identified for curriculum development on the BSc CAPD, which included specialist modules available for selection by students and links with industry for design projects which are documented in the chapter.

Proven techniques developed by 'Delft' for Computer Aided Learning (CAL) in the area of technical communication suggested potentially wider applications in the broad area of design.

The advances being made in both 2D and 3D CAD software also indicated the possible development of CAL software in the BSc CAPD curriculum; these initiatives are discussed in Chapter 3.

2.1 The Dutch Education System

2.1.1 Background To The Netherlands

The Netherlands is one of the world's most densely populated countries, the population of approximately 15 million people live on land covering an area less than 34,000 square Km.

With Rotterdam one of the world's busiest ports, the Netherlands is a prosperous country, due to its role in international trade, agriculture, and its advanced industries, with the added advantage of its central location in Europe.

Like most European countries, the Netherlands is highly advanced in education, research and technology. Dutch research and education enjoy an international reputation in many fields, for example electronics and design. This is backed by pioneering research from multi-national corporations such as Philips, Unilever and Shell whose headquarters are situated in the Netherlands.

The country is internationally oriented, the majority of Dutch people understand English and many speak at least two foreign languages. It is ranked second in Europe and seventh in the world in the fields of science and technology, giving it a world wide reputation.

In recent years the number of foreign students in the Netherlands has grown. The government, universities and *hogescholen* have made it more attractive for students from other countries to study in their institutions. Many offer courses that are conducted in English, and the European Union's student exchange programmes offer students from member states the opportunity to carry out part of their studies in another member state.

Most exchange programmes (Ref:- [3]'Study in Europe' 1993 pp. 8-9) were covered under either COMETT, ERASMUS or LINGUA funding. The COMETT grant was designed to promote and foster co-operation between industry and higher education in technological fields, ERASMUS covered student exchange between higher education institutions in member states, where as LINGUA had much in common with ERASMUS but was specifically for students studying foreign languages. The ERASMUS and COMETT grants have since ended and have been replaced by [4]SOCRATES and [5]LEONARDO funding.

During the academic year of 1991-92 approximately 10,000 foreign students visited the Netherlands to study.

2.1.2 The Dutch Education System, Pre-University

Dutch Universities are open to any student who has gained the appropriate type of secondary-school diploma. (Ref :- Fig 2.1 Diagram of the Dutch Education System)

To qualify for admission to universities students must hold a diploma from a secondary school offering a pre-university called a 'VWO' programme, to which admission is highly selective. The duration of the 'VWO' programme is six years which commences after eight years of primary education. During the first four years of the 'VWO' programme pupils study Dutch plus three foreign languages (French, English and German), and subjects such as biology, geography, history, social science, art and physical education.

[3] *Study in Europe, Higher Education Opportunities*. (1993) Department for Education. London: DFEE Publications Centre, pp.8-9.
[4] SOCRATES Guidelines for Applicants (1998) –Part II. DFEE Pub, pp. 31-49
[5] LEONARDO DA VINCI programme (1999) *A guide for applicants in the UK*. DFEE Pub, pp.1-4.

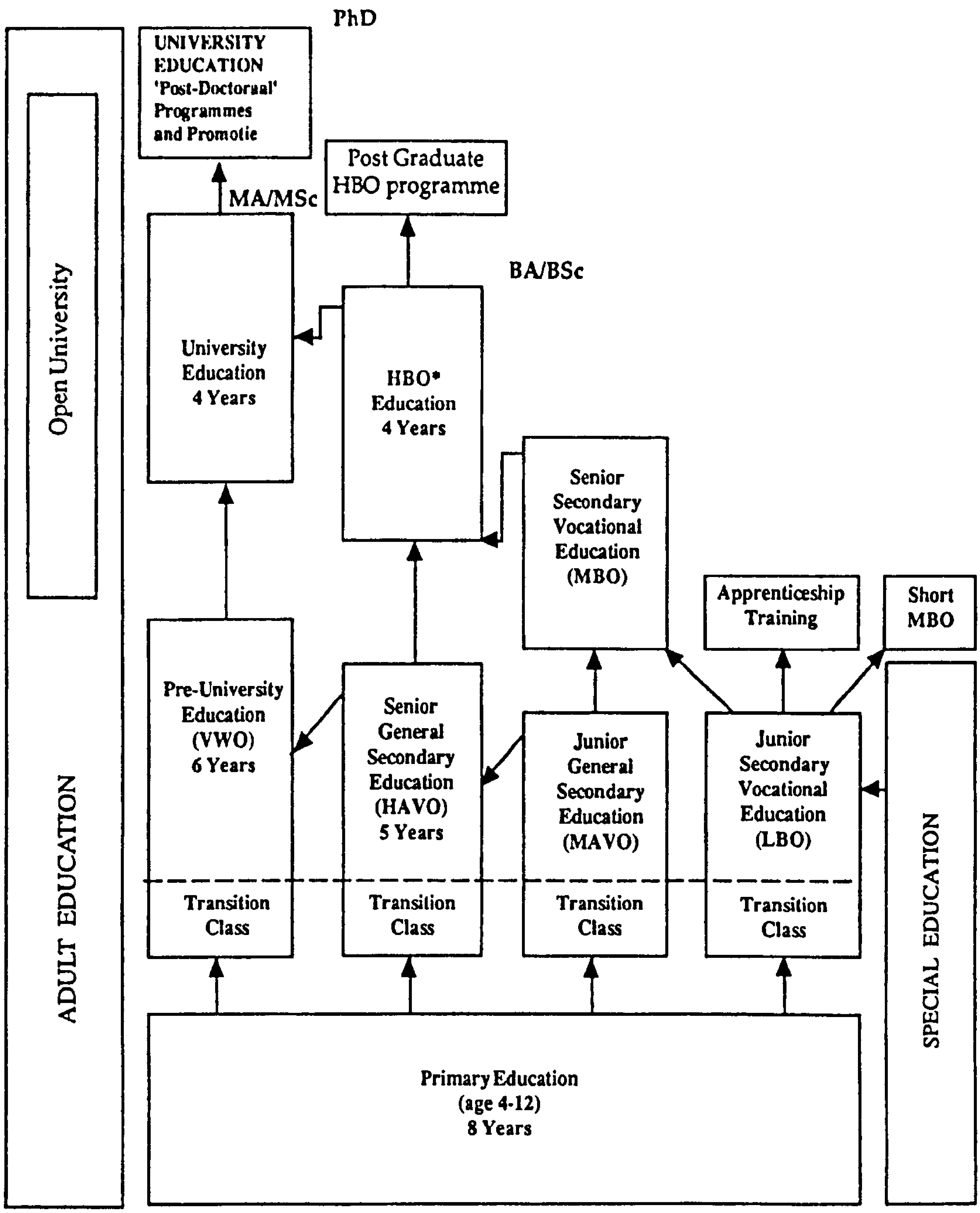

Fig 2.1 Diagram of the Dutch Education System

In the final two years, pupils concentrate on seven examination subjects, Dutch and one foreign language (English, French, or German) are compulsory with the remaining five selected from mathematics, physics, chemistry, biology, English, French, German, geography, history, Latin, Greek, Law, commerce, Art and economics.

State examination finals in all seven subjects are the same for all 'VWO' schools, these national examinations guarantee a uniform level.

For some specific areas of study, University admission, also require certain subjects to be included in the 'VWO' examination this is a requirement by law. In the case of Delft University of Technology, an examination in the subjects of mathematics and physics is a requirement for admission.

In the Netherlands secondary schooling that grants admission to university is only given to the highest achievers.

2.1.3 Structure of Higher Education in the Netherlands in Comparison with the UK

With reference to Fig 2.1 'Diagram of the Dutch Education System' higher education in the Netherlands is divided broadly between: -

- **i)** Higher professional education 'HBO' (HBO = *hoger beroepsonderwijs*) which is offered at Polytechnics and Colleges (*hogescholen*) and
- **ii)** University education .

HBO or the *hogescholen* prepare students directly for careers and vocational activities requiring applied academic or scientific knowledge and therefore tend to be more practically oriented. Universities tend to train students for the individual pursuit of knowledge and for independent practice of science in an academic or professional setting. It includes both specialised professional training and broadly theoretical studies.

In recent years the two types of institution have grown closer in their approach and transfer from one type of higher education to another is possible similar to the UK, reference Fig 2.2 'Diagram of the English Education System'. The UK however, has seen the number of qualification routes into University increase, as shown on the diagram. Students are accepted in UK Universities from the traditional 'A Level', BTEC national or diploma route, GNVQ route, foundation programmes, or mature students who have completed an access course into higher education.

The formal length of study programmes in Holland is generally four years for both universities and *hogescholen,* although students can be allowed more time to complete, up-to six years in some cases for the *'doctoraal'* programme. This is confirmed from my own discussions with students and lecturing staff from the Industrial Design course at TU Delft where very few students finish in the minimum time, possibly due to the severity of the course programme, i.e. the number of modules which must be passed by students coupled with an extensive design and make project in the final year.

The academic year is long in the Netherlands, starting at the end of August and ending in mid-June, compared with UK Universities, starting early October and ending in June. Course programmes in Holland require 40 hours per week study, similar to the UK, to include contact hours and hours for independent work.

The 1993/94 Nuffic publication [6]'Studying in the Netherlands' states "The Netherlands has a long tradition of academic freedom and autonomy. The universities and HBO institutes, or *hogescholen,* determine the content of their own study programmes and research. But they are not ivory towers. By tradition, their feet are firmly planted in society this is true both literally and figuratively. Universities and *hogescholen* are

[6] *Study in the Netherlands.* (1993/94) Nuffic publication, Netherlands organisation for international co-operation in Higher Education., The Hague, The Netherlands, pp.6-7.

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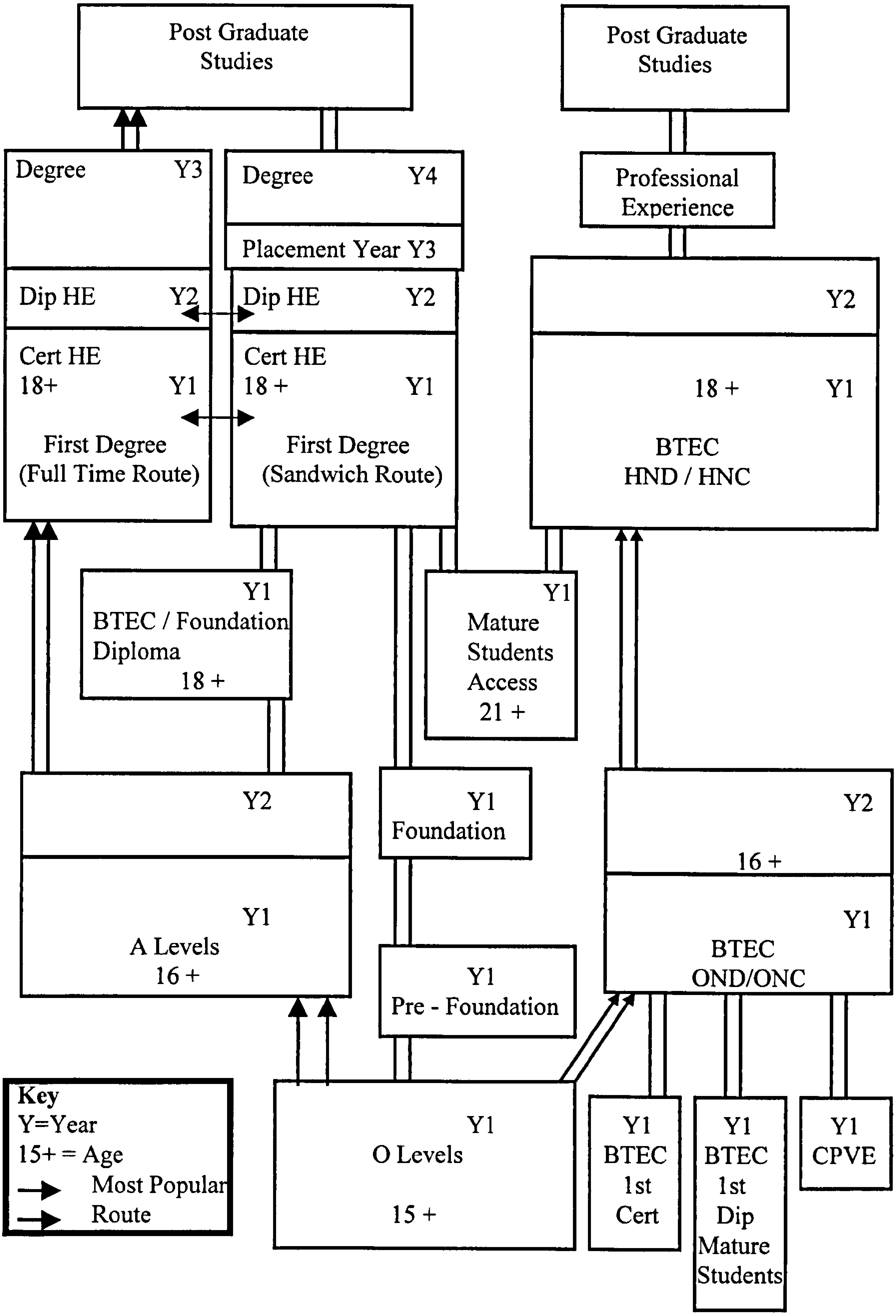

Fig 2.2 Diagram of the English Education System

situated in the middle of cities, and they feel closely involved in social needs for knowledge, skills and technology"

Unlike the Dutch system, this academic freedom and autonomy, whilst present in the traditional Universities within the UK, has not always been available to other higher education institutions, until the granting of University status to Polytechnics during 1992 - 1993.

In the late 1980's and early 1990's a large percentage of UK higher education institutions moved towards a quantitative approach to increasing the number of full-time students on their courses, rather than a qualitative approach. This maybe attributed to institutions being in direct competition with one another for student numbers and UK Government funding being based on the number of students enrolled. However, many institutions complained of a short fall in extra funding in real terms for equipment and facilities to meet the higher number of students attending higher education at the time.

2.1.4 Higher Professional Education (HBO)

Dutch government publications in English often refer to HBO as Higher Vocation education, the HBO institutions themselves prefer the term Higher Professional Education.

HBO is practically oriented, preparing students for vocations and professions. Most of the institutions have close ties with trade and industry that employ their graduates and Chambers of Commerce via regional networks. These contacts with industry allow the *hogescholen* to adjust their programmes quickly to the changing needs of the labour market and specific career requirements.

In the past, education offered at HBO has been compared to that of the *Fachhochschulen* in Germany and the old style Polytechnics in Britain.

There are currently more than 80 *hogescholen* offering (HBO). Approximately one-third are teacher training colleges offering only one study programme, the rest offer a variety of programmes including: - social welfare, health care, agriculture, education, arts, commerce, and technology. Enrolment averages 2000 and varies from 13,000 down to 600.

2.1.4.1 HBO Study Programmes

The first year of a HBO programme is devoted to general subjects. This first year is often known as the *propaedeuse*. Students then specialise in one of these subjects in the second year. The majority of the third year is spent gaining practical experience in a working environment. The fourth year covers an individual project and thesis.

2.1.4.2 HBO Degrees And Awards

HBO titles may only be used by recognised institutions, the graduates using the title of *baccalaurens,* often abbreviated to *bc.* However in agriculture and technology the title of *ingenieur* is used abbreviated to *ing* . HBO graduates also have the right to use the international title of Bachelor.

2.1.4.3 HBO Advanced Study Programmes

Further study programmes are available in nearly all HBO sectors, some leading to postgraduate diplomas others to accredited Masters degrees. HBO graduates are also eligible to pursue a doctorate at a university.

2.1.5 Dutch University Education

There are 13 universities in the Netherlands, the oldest dates from 1575 at Leiden and the youngest was founded in 1976 at Limburg. Average enrolment is 12,000 students . As well as these traditional institutions the Dutch Open University offers distance learning at University and HBO level. Credits obtained at the Dutch Open University are accepted at the British Open University and vice versa.

Programmes of study offered differ from one university to another. One specialises in agriculture (Wageningen), nine offer education in a broad range of fields, these are the universities of Leiden, Amsterdam, Gronihgen, Utrecht, Limburg, Nijmegen, Tilburg, Rotterdam, and the Free University Amsterdam.

There are three Universities that specialise mainly in engineering. Delft, Twente, and Eindhoven. With reference to [7]'General Information (1989)' document, Delft University of Technology is the largest technical institute in the Netherlands with a teaching and research staff of 1400, support staff of 2400 and 13000 students.

2.1.5.1 University Degree Study Programmes

There are two levels of education available in Dutch Universities, the first covering the four-year 'doctoraal' degree, the second being *'post-doctoraal'* advanced training and research programmes.

The degree programme for the *'doctoraal'* officially takes four years of study at universities in the Netherlands. However, because the academic programme is so demanding, few students complete their studies within the four years, students then have

[7] *General Information.* (1989) Delft University of Technology (TU Delft). Public Relations Department, P.O Box 5, 2600 AA DELFT, The Netherlands, p.8.

the opportunity to register and extend the programme to a total of six years, by which time studies must be completed.

Upon entering the university, students follow the curriculum set out for their specific chosen field of study. The first year of the course, known as the *propaedeuse*, sets a general introduction to the chosen field of study. This contains a number of prescribed modules within the discipline, and thus gives a sound foundation for the increasingly specialised subsequent years.

At the end of the first year there is a preliminary examination. Students who have not successfully passed their *'propaedeuse'* examination by the end of the second year are not permitted to continue their studies in any of the Dutch Universities.

Students must pass a specified number of written and oral examinations called '*tentamens* ' for the '*propaedeuse*' and '*doctoraal*' examinations. On average 20 % of enrolled students drop out in the first year, with a further 10% who elect to change their course. At a national level the drop out rate is close to 20 % for the entire '*doctoraal*' programme.

Depending upon the discipline, the ratio of specified to elective courses varies. In the final year the programme can be specialised depending upon the student's chosen career path, with the focus being in a professional or academic area. For each year that follows there is an increasing degree of specialisation in the chosen field, and students have more freedom in selecting their own subjects as they progress, the final year requiring a thesis based on the student's own independent research project. This thesis in Dutch is known as the ' *doctoraal scriptie* '.

Dutch University students are encouraged to work on their own initiative, gathering material from libraries, and to contribute actively when working in-groups. Group work tends to alternate with lectures. Tuition takes the form of lectures, seminars and practical work with lecturers tending to assemble teaching literature into readers, required reading forms the core of most courses.

An attempt was made to standardise the study workload in terms of study points, but not all Universities use this system. For the Universities that do apply it, the workload is 40 hours a week, to include lectures laboratory and independent study. The University of Wolverhampton also applies a 40-hour per week guideline, where students study four modules per semester. Each module includes 10 hours of study per week, which is a mixture of lectures, tutorials, laboratory work and self directed study depending upon the module content. An academic year in the Netherlands lasts 42 weeks, which results in a study load of (40 hours*42 weeks) = 1680 study points per year, or (1680 study points* 4 years) = 6720 study points for the whole programme. Some universities use an alternative, more condensed version of this system where 1 unit of study is granted for 40 hours of work. The total number of units required for the entire programme is 168.

The grading system used by Dutch universities is based on a numerical scale ranging 1 (very poor) to 10 (outstanding). The lowest pass grade is 6, and it should be noted that 9's and 10's are rarely given.

Graduates from the 'doctoraal' programme are usually well qualified for employment in demanding and responsible positions.

2.1.5.2 University Degrees And Awards

University titles are legally protected in the Netherlands, conferred only by institutions that meet the same, high standards. There are also specific legal rights connected to the *'doctoraal '* degree, which have both academic and professional values.

Graduates of a *doctoraal* programme may use the title *'doctorandus'*, which is abbreviated to *drs*. in front of the name. However in law and engineering the titles of *meester* (*mr.*) and *ingenieur* (*ir.*) are used respectively. The introduction of the University Education Act of 1986 has made it possible for *'doctoraal'* graduates to use the international title of 'Master ', abbreviated with an 'M' after their name. After completing the programme at TU Delft the graduate receives the degree 'Ingenieur' (ir., M.Sc.)

2.1.5.3 University Advanced Study Programme

The majority of students' academic careers end with the doctoraal; however, there are a number of '*post - doctoraal*' advanced training and research programmes, the highest possible academic achievement in the Netherlands being the '*doctoraat*' (dr.) or '*promotie*'. The Dutch doctorate is comparable to a Ph.D.

It is a requirement in some professional fields to complete post-doctoraal training. In the areas of Medicine, pharmacy, accountancy, and veterinary science this is a further two years, with dentistry and teaching requiring one extra year for qualification.

2.1.6 Industrial Design Engineering, TU Delft, Holland

During 1970, following industrial feedback at Delft the Department developed a four-year course in Industrial Design Engineering. Industries were seeking designers who could combine the skills and theoretical knowledge of an engineer and the conceptual ideas of the industrial designer. The University of Wolverhampton's BSc CAPD degree programme was based on a similar premise. The aim was to move away from what I term "Over the wall design", i.e. the designer who produces concept designs and then discharges the design to the production / manufacturing engineers to sort out and produce. What was required was a designer who could work at both ends of the design spectrum; be able to produce design concepts but also have the technical knowledge to communicate effectively with materials and production engineers and take the design through to the prototype stage to achieve the product goal.

2.1.6.1 The Old Curriculum

The educational programme of Industrial Design Engineering was developed and aimed at integration of four different disciplines which are related to the four departments within the faculty (Ref :- Fig 2.3 Faculty of Industrial Design, Delft University of Technology, Holland). These disciplines are: -

- Mechanical Engineering Design.
- Aesthetic design related to form theory and the applied arts.
- New product development related to business administration.
- Product and system ergonomics covering both the psychological and bio-mechanical approach.

In each of these areas lectures and exercises are given to students who must pass a set number of examinations. Much emphasis is placed on the integration of the specific knowledge and skills of the four disciplines. Students therefore have to participate in a number of design projects that form the backbone of the course structure. For the graduation project the student had not only to write a thesis on a product's development but also had to present a model or prototype of the design undertaken. This integration and project approach to design education is very similar to that adopted by the BSc CAPD course.

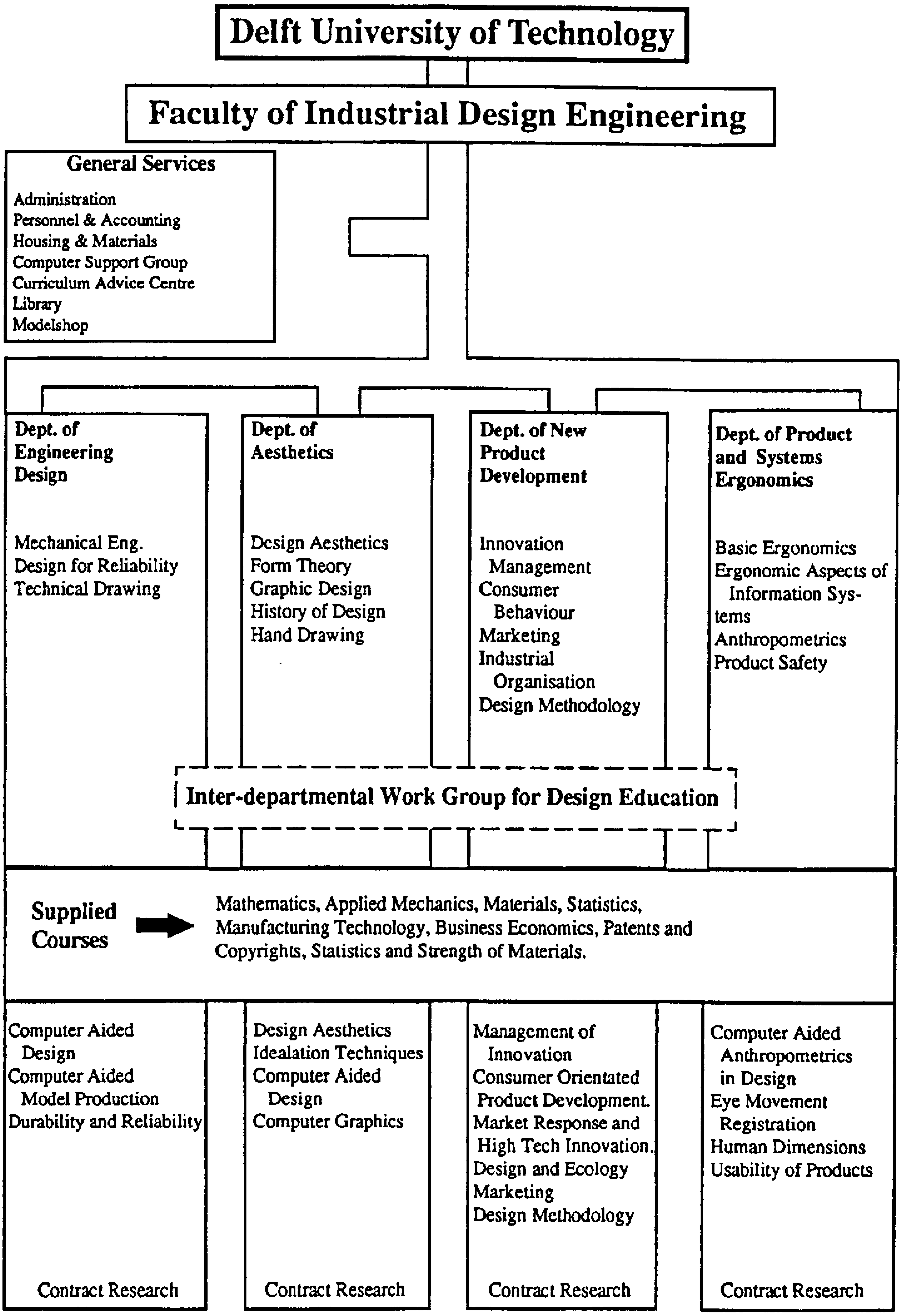

Fig 2.3 Faculty of Industrial Design, Delft University of Technology, Holland

The design programme at Delft gives a broad education to its engineers. However, the curriculum offered only a limited amount of time for specialisation. About 700 hours, 10% of the total curriculum is set aside for elective courses.

The programme was based upon an average work load of 1700 hours for the student, to include lectures, exercises, projects and laboratory work etc. The department used a scale of 100 credit points per year, each credit point equivalent to 17 hours. Each academic year is divided into four periods of ten weeks, the first seven weeks of each period is devoted to lectures and examinations take place in weeks nine and ten.

The University of Wolverhampton's academic year is shorter in comparison, consisting of two semesters, each semester made up of 12 weeks of lectures, followed by 1 revision week and two weeks of examinations. Students study four modules per semester.

Delft's design curriculum consists of a large number of modules per year, each module having separate examinations and assessments. Students' pass when they have attained at least a grade 5 in one module and all other modules with a grade 6 or higher. However, for the design projects grade 6 or higher must be obtained.

2.1.6.2 The New Curriculum

In 1990 the Faculty of Industrial Design Engineering started to renew and update its curriculum to take into account government funding and legislation. By 1993/1994 a new first year was started which formed part of a four-year programme.

Some important changes had taken place to make the curriculum more suitable to the development of successful engineers in the future. Subject content was updated, specialisation modules, new time schemes, better integration between subjects and design projects, and more attention given to the relationship between research and education. The faculty had to deal with Dutch laws and regulations and this led to certain characteristics such as funding for students and the length of the degree programme. Although the curriculum was officially four years the final level of the engineering course compares to the MSc. As a result of this most students were overloaded for four years. In 1995/ 1996 it was therefore changed to a five-year programme, students have experience in a variety of subjects and participate in many different practical design projects. Subjects include: -

- Product aesthetics.
- Ergonomics.
- Product design and design methods.
- Computer Aided Design.
- Environmental aspects of product development.
- Mechanical Engineering.
- Materials application.
- Product safety.
- Marketing.

With reference to [8] "Objectives of the Industrial Design Engineering Educational Programme" (1995/1996) at TU Delft, their Web page lists the following twelve common objectives of Industrial Design Engineering as: -

1) applying creativity in product design,
2) solving open-ended design problems,
3) achieving competence in written and oral communication in the Dutch and English languages,
4) acquiring appropriate skills in computer aided design techniques,

[8] *Objectives of the Industrial Design Engineering Educational Programme* (1995/1996) TU Delft ID Curriculum.<http://www.io.tudelft.nl/education/ects/delft4>

5) attaining a professional and academic attitude,

6) developing and using modern design theory and methodology, including aspects of aesthetics and ergonomics,

7) formulating design statements and specifications, considering alternative solutions,

8) making a simple and/or presentation model

9) feasibility and production processes in the organisational and market context,

10) insight into the fundamentals of labour law and the human aspects of management, economic factors, safety, reliability,

11) participation in multidisciplinary project (design) teams in an industrial context,

12) ability to plan and assess his/her own work and the work of others.

The "old" curriculum did not contain specified specialisation parts but students could choose from free choice subjects. Developments in the field of Industrial Design Engineering have forced the curriculum to be split into two specialisation areas which were introduced in 1996/1997: -

- **Product Development**
- **Innovation-Management.**

This was achieved by limiting the free-choice possibilities to students and varying the amount of study points for certain aspects in the curriculum.

In the scheme set out in (Fig 2.4 Industrial Design Engineering (I.D.E.) curriculum Content, TU Delft) a comparison is made between the old curriculum and the two new main specialisation programmes.

The study load is stated in study points, where 1 study point = 40 hours of study.

	NEW		NEW		OLD	
	Product Development		**Innovation Management**			
	sp	**(%)**	**sp**	**(%)**	**sp**	**(%)**
Mathematics & Physics	15	(8.9)	17	(10,1)	14,6	(8,6)
Technology & Mechanical Engineering	35	(20,8)	27	(16,1)	32,8	(19,2)
Informatics & Electronics	15	(8,9)	13	(7,7)	10,8	(6,3)
Scientific Research	4	(2,4)	4	(2,4)		
Synthesis (Design Project)	49	(29,2)	49	(29,2)	51,6	(30,3)
Aesthetics	15	(8,9)	10	(6,0)	15,6	(9,1)
Ergonomics	11	(6,6)	6	(3,6)	9,3	(5,5)
Management & Marketing	12	(7,1)	31	(18,3)	15,8	(9,2)
Other	6	(3,6)	5	(3,0)	2	(1,2)
Free Choice	6	(3,6)	6	(3,6)	18	(10,6)
Total	168	(100,0)	168	(100,0)	170,5	(100,0)

Study load expressed in "study points". 1 study point means that a student has to spend 40 hours on a subject. The figure in ( ) corresponds with a percentage of the sum. In this scheme the "old" curriculum (without specialisation) is compared to the complete new specialisation programmes.

Fig 2.4 Industrial Design Engineering (I.D.E.) curriculum content, TU Delft.

The programmes are described on a rather abstract level as the detailed names of the subjects may not give a clear insight into the programmes. However, special attention is given to the environmental effects of design, design methodology and telematics. Telematics covers a range of information and communications technology (ICT) such as multi-media, Tele-learning, mobile communication, electronic commerce and the Internet.

The communal part of the curriculum contains 109 study points out of a total of 168. This also explains why the differences are still comparatively small between the specialisation parts.

Something that is not apparent from this scheme is that students also have the opportunity to choose a specialisation in 'research' or 'professional practice' in either Product Development or Innovation Management. The objectives listed for each specialisation are: -

Product Development (professional practice) the ability to successfully integrate elements of form-giving (form-giving is translated from the Dutch word 'Vormgeven' meaning to give shape/form), product and systems ergonomics, engineering and marketing into a 3D product.

Product Development (research) the knowledge of theory and methods on form-giving, product and systems ergonomics, product engineering and marketing for 3D products, with an emphasis on research and the ability to generate new knowledge in the field of product development.

Innovation Management (professional practice) the ability to successfully integrate product innovation, product development and design conceptualisation, within the company's policy and to co-ordinate this with other parts of the company and its markets.

Innovation Management (research) the knowledge of theories and methods to integrate product innovation, product development and design conceptualisation within the company's policy and to co-ordinate this with other parts of the company and its markets, with an emphasis on research and the ability to generate new knowledge in the field of innovation management techniques and structures for the organisations involved.

The space in the curriculum for these sub-specialisations is taken from the hours allocated for the design projects.

Therefore, for the first three years the programme of study consists of compulsory modules and practical exercises. Before the start of the fourth year students must choose between Product Development and Innovation Management, and after three blocks in the fourth year students must choose within their chosen specialisation between either participating in design projects 6 and 7 or a project that is research oriented. Project 6 teaches students the different models of the design process and broadens design methodology. For design project 7, students design a product in an industrial context by working in a multi-disciplinary team with representatives from both Product Development and Innovation Management.

The fourth year consists of obligatory courses in their chosen specialisum. In the fifth year students finish Design Project 7 or a research project dependent on their choice, with an emphasis either towards 'research' or 'professional practice'. The greater part of the fifth year is spent on their Master's Project.

The Master's Project is chosen following liaison between the professor and student, the project subject is often based upon the professor's interaction and experience with industrial companies. The Master's Project usually takes 6-9 months, and is carried out individually but coached by a professor and a small team of scientific staff who do not necessarily belong to the same Faculty department. In most cases the staff are from other Faculties, or other universities and sometimes from abroad. Most students carry out their Master's Project in a company, but it is also possible to carry out their project within the Faculty in one of its research areas. In the new programme for the 'professional practice' sub specialisation, the project is usually industry based and is carried out within and for the company, and often consists of the development of a new or existing product or a product marketing policy. From 1997 onwards the research project for the 'research' sub specialisations has to be carried out within one of the Faculty's laboratories, an external research organisation, or a research and development department of an industrial company.

A profile of the M.Sc. graduate in industrial design engineering from TU Delft is given on their Web site under the title reference [9]'The Character of the Educational Programme' (1995/1996) and states: -

"The industrial design engineer is a technologist as well as a designer and is able to master the sub-disciplines that are needed to design new products. Product development is a tool for the satisfaction of market needs, including those of the individual users and trade and industry. The industrial design engineer occupies a co-ordinating position in the product development team and he/she speaks the language of most other technical specialists and of marketers. Graduates of the programme usually find employment in industry, product design consultancy, research institutions and organisations. After a few years of professional experience he/she will be able to initiate, manage and coach the design of durable consumer products and professional equipment and advise about decisions concerning marketing and product policy".

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[9] *The Character of the Educational Programme* (1995/1996) TU Delft ID Curriculum.<http://www.io.tudelft.nl/education/ects/delft3>

2.1.6.3 Research Activities

The TU Delft, School of Industrial Design Engineering places a great deal of emphasis on aspects of both fundamental and applied research. Students are confronted with different aspects of scientific research during their study schedule, a great deal of which is aimed at improvement of the quality of the product design and development process. The ultimate goal is to optimise the process of innovation in industrial/product design. The research programme includes:

- Computer Aided Design and Manufacture (CAD/CAM),
- Man-product interaction,
- Management, marketing and systematic product development,
- Design for reliability,
- Telematics and information technology and its influence on the industrial design profession.

The research themes in the field of Industrial Design Engineering are subdivided into eleven subject groups: -

i) Aesthetics and product design

ii) Applied ergonomics

iii) Environmental product development

iv) Information exchange in man-product interaction

v) Innovation management

vi) Marketing and market research

vii) Perceptual aspects of innovation

viii) Physical factors of man-product interaction

ix) Reliability of plastic products

x) Technical product information

xi) IDEATE, CAD

(IDEATE is a word TU Delt invented from a combination of Idea and Create. It is used to describe a research group and its activities. The research is centred on supportive tools, methods and techniques that support designers in the early form-creation phases of the design process. In this context, the ability to create form and express ideas is of utmost importance hence the 'play' on the two key words.)

From the comprehensive list above it can be seen that research into many fields of product design is carried out. The author's visits to TU Delft and industrial contacts assisted in identifying a number of possible interesting areas for further research, these include: -

1) Curriculum development for the BSc CAPD course to include specialised modules made available for selection by students.
2) Development of closer links with industry for live design projects i.e. the integration of industrial based design and innovation into the curriculum.
3) Computer based Learning Packages or Computer Aided Learning (CBL/CAL). Computer Aided Design and 3D modelling have always played an active role in both institutions and evaluation is always ongoing. Just two of the many software packages which have established themselves on the industrial design course at TU Delft and the BSc CAPD course at Wolverhampton are 'AutoCad' and 'Pro-Engineer'. The advances being made at that time in both 2D and 3D CAD software indicated possible development of CAL software in these areas as assisting in dealing with large number of students on CAD modules.
4) New methods of delivery of these computer based learning packages over a distance learning environment. This would later include making use of Video Conferencing,

at the time a technology still in its infancy, and the Engineering Broadnet project developed by the author and a colleague for teaching 2D CAD. These are discussed in detail in the next chapter.

2.2 Courses In Product Design UK

Prior to 1994 student applications to institutions for BSc, BA and HND design courses could be made via the Art and Design Admissions Registry (ADAR), the Polytechnics Central Admissions System (PCAS), and the Universities Central Council on Admissions (UCCA), or mature students could apply direct. Therefore, statistics on the number of student applications/acceptances and the number of product courses are difficult to collate for this period. A simplified joint system for applications was introduced in 1994 called the Universities and Colleges Admissions System (UCAS).

2.2.1 UCAS Applications And Ratios For All Design Subjects, 1994-1998

Figure 2.5 shows statistics for the five-year period 1994-1998 that has been extracted from [10]UCAS data via their Web site. The tables include the year, the total number of applications, total number of accepted applicants and the ratio of applications to acceptances for these years. The statistics for UCAS 'Design studies W2' subject group refer to all types of design including General Art and Design, Product, Interior, Textile, Graphic and many more.

In the context of UCAS, applications refer to the sum totals of all the applicants' selections, and, as such, do not count the individual.

For 1994 and 1995 entries, a total of eight applications were available to each potential student applicant; for 1996 entry and subsequent years, this was reduced to six applications.

The definition 'accepted' means those applying through the UCAS scheme, who were ultimately accepted to courses offered in the United Kingdom of Great Britain and

[10] UCAS UNDERGRADUATE COURSE SEARCH. *UCAS Applications and ratios for Design Studies Subject Group, 1994-1998.* UK. <http:/www.ucas.ac.uk>

Year	Subject group	Number of Applications totals	Number of Accepted total	Ratio of applications to accepted
1998	Design studies W2	66,730	13,491	4.9 : 1
1997	Design studies W2	65,373	13,251	4.9 : 1
1996	Design studies W2	19,599	2,219	8.8 : 1
1995	Design studies W2	21,522	1,905	11.3 : 1
1994	Design studies W2	25,681	1,657	15.5 : 1

Fig 2.5 UCAS Applications And Ratios For Design Studies Subject Group, 1994-1998

Northern Ireland. It can be seen from the figures that for 1994, 1995 and 1996 there was a steady increase in the number of art and design students accepted, from 1,657 to 1,905 and 2,219 respectively. However, in 1997 the number of total applications shows a significant increase with the number of accepted students reaching 13,251, an increase of [(13,251-2,219) / 2,219] * 100% = 497% on the previous year. Much of this increase can be attributed to the integration of ADAR with UCAS; design courses previously dealt with by ADAR were now included in UCAS figures. Likewise, in 1998 the number of "accepted" totals maintains this figure, showing a slight increase to 13,491.

With reference to [11] an article in 'THE INDEPENDENT' newspaper (4th December 1999) title "Art students have no chance of getting Jobs". Art and Design courses have become the UK's most popular and fastest-growing subjects, with an estimated 72,000 people studying courses in art and design at various levels i.e. degree level and below, at Universities and colleges. The argument is that many of these people can't get work as a professional artists or designers. However, what is proposed is that art and design courses provided a very good education in transferable skills, problem solving, life skills and self-confidence, preparing students for the new creative economy that replaced the industry-led Britain of the past. Many graduates diversify and find work in the expanding communications industries, media and the Internet led companies.

2.2.2 Product Design Courses in England, Northern Ireland, Scotland and Wales.

As previously discussed prior to 1994 there were a number of routes that students could follow to apply to higher education establishments for product design courses. Because of

[11] 'THE INDEPENDENT' newspaper (Saturday 4th December 1999) title *"Art students have no chance of getting Jobs"* by Lucy Hodges, Higher Education Correspondent.

this a search was carried out on UK institutions by the author at the start of the research programme during 1993/1994 to determine the number of institutions advertising design courses in particular Product Design or Industrial Design and the number of students applying for these design courses. [12]ADAR publication, University/Higher Education prospectus details and the Design Council's' handbook [13] 'Design Courses 1993/94' were used as reference.

From this a listing was compiled showing the institution, course description and approximate number of places available, reference Appendix 1, (List of Product Design Courses in England, Northern Ireland, Scotland and Wales, 1993/1994 3-page listing). Each institution was contacted by telephone to establish the approximate number of first year student places made available, these figures appear in the right hand column. Some institutions would not disclose this figure, therefore it appears as not available, abbreviated to 'NA' in the column. The figures (1993/94) showed no less than 42 colleges and Universities offering a form of higher education in Industrial / Product Design, of these 42 institutions 33 offered degree level courses at either BSc or BA in Industrial Design or Product Design.

In the majority of cases these institutions are in direct competition with one another for student places. During the 1993/94 period the average intake of first year students was approximately 25 per UK institution, exceptions to this were Central Saint Martins College of Art and Design with 50, Brunel University and Bournmouth University, who approached 90-100 students for their intake. Based upon these 42 institutions, an estimate of the overall number of available student places at this time was approximately 1,100, assuming a figure

[12] *Art and Design Courses 1993*, BA/BA(Hons)/BSc and HND COURSES: ADAR handbook, UK.
[13] *Design Courses 1993/94*, UK. Publ, The Design Council.

of 20 students for those institutions who would not disclose their intake. This figure drops to approximately 700 student places when taking into account specific 'Product Design' courses. This figure of 700 will be used later in determining the available capacity.

Fig 2.6 shows statistics for UCCA and PCAS applications to Product Design courses for 1992 provided by [14]UCCA statistics department 16/09/93. Although the total applications figure of 1619 appears high in comparison to the total accepted applicants of 287, one has to take into account that these are multiple applications and some students could have submitted as many as 8 applications. Of the 287 accepted students 200 (69.7%) were male and 87 (30.3%) female. The 12 overseas students amounted to only 4% of the total. No ADAR application statistics were available, however, when comparing the accepted figure of 287 students with the Authors estimated figure of 700 Product Design places available. This indicates a substantial amount of spare capacity in the system.

Fig 2.7 shows tabulations of UCAS applicants for the years 1997 and 1999 relating to Product Design courses. (Reference: - [15] UCAS Department of Research and Statistics). Bearing in mind that in 1997 ADAR and UCAS figures were integrated for the first time, the number of applicants shown in both years refers to a person and not multiple applications. Therefore of the 1,300 students who applied in 1997 only (27.6%) 359 were accepted. Of those 81.6% were male and 18.4% female. The 39 overseas students accepted accounted for approximately 10% of the total.

By 1999 the number of applicants increased by 353 (27%) to a total of 1,653 compared with the 1997 figures and the number of accepted applicants increased by 195 (54.3%) to a

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[14] UCCA and PCAS Applications to Product Design courses UK (1992). UCCA statstics Department, enq 701, UK. accessed 16/09/1993.

[15] *UCAS Applicants to Product Design courses UK, (1997 and 1999).* Dennis, Richard. UCAS Department of Research and Statistics, Cheltenham, Glos, UK.

All UK & Overseas Applications to Product Design courses via UCCA and PCAS, 1992

	UK			Overseas			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
UCCA	626	280	906	51	18	69	677	298	975
PCAS	537	73	610	26	8	34	563	81	644
Totals	1163	353	1516	77	26	103	1240	379	1619

All UK & Overseas accepted Applicants to Product Design courses via UCCA and PCAS, 1992

	UK			Overseas			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
UCCA	114	75	189	8	1	9	122	76	198
PCAS	76	10	86	2	1	3	78	11	89
Totals	190	85	275	10	2	12	200	87	287

Fig 2.6 UCCA and PCAS Applications to Product Design courses, 1992

All UK & Overseas Applicants to Product Design courses, 1999

UK			Overseas			Total		
Male	Female	Total	Male	Female	Total	Male	Female	Total
1,259	243	1,502	81	70	151	1,340	313	1,653

All UK & Overseas accepted Applicants to Product Design courses, 1999

UK			Overseas			Total		
Male	Female	Total	Male	Female	Total	Male	Female	Total
430	68	498	27	29	56	457	97	554

All UK & Overseas Applicants to Product Design courses, 1997

UK			Overseas			Total		
Male	Female	Total	Male	Female	Total	Male	Female	Total
1,006	169	1,175	73	52	125	1,079	221	1,300

All UK & Overseas accepted Applicants to Product Design courses, 1997

UK			Overseas			Total		
Male	Female	Total	Male	Female	Total	Male	Female	Total
269	51	320	24	15	39	293	66	359

Fig 2.7 UCAS Applicants to Product Design courses, 1997 and 1999

total of 554. Of this total of 554 accepted, males accounted for 82.5% and females 17.5%. The 56 overseas student accepted accounted for approximately 10% of the total.

Overall the figures for 1997 and 1999 indicate the percentage of male and female students accepted onto courses remains the same, approximately 82% and 18% respectively, also overseas students represent 10% of the total for both years. However, growth is shown in the number of applicants and accepted applicants, 27% and 54% respectively, between 1997 and 1999. The 554 successful applicants in 1999 would still not have filled all the places that had been available in 1993/94.

During the 1990's there has been a steady growth in the number of institutions offering Industrial or Product design degree options. During 1999 [16]UCAS began to provide data on their Web site highlighting the number of institutions offering product design programmes, reference Appendix 1, (UCAS List of Product Design Courses in England, Northern Ireland and Wales 1999, 8 pages). This data shows that the number of institutions offering BSc or BA courses had risen from 33 to 58, [(58-33) / 33] * 100% = 75.75% increase over 6 years. The development of modularity programmes also encouraged a significant expansion in Product Design options and themes.

While 1999 showed a significant growth in student numbers being accepted on Product Design programmes (554) there was nonetheless significant spare capacity. Clearly a situation of too many institutions chasing too few students.

The BSc CAPD course at the University of Wolverhampton was one of the first 'Computer Aided Product Design' courses in the country, commencing in 1989. By 1999/2000 the

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[16] UCAS UNDERGRADUATE COURSE SEARCH. *Product Design courses in the United Kingdom 1999/2000.* UK. <http:/www.ucas.ac.uk> accessed 16/03/2000.

popularity of utilising computer-based tools in Product Design had increased to ten the number of institutions offering BSc, BA or HND courses with the title 'Computer Aided Product Design'. Reference Appendix 1 [17](UCAS List "Computer Aided Product Design Courses in the UK", 1 page)

Difficulty has been experienced in gaining satisfactory data for enrolment figures on CAPD "like" courses across other institutions, however, figures for the University of Wolverhampton's BSc CAPD are provided in Table 2.1 for 1989-1999 on the next page. It can be seen from the figures that enrolment targets have regularly been achieved over the years and when compared to the general figures for places being taken up by Product Design students the BSc CAPD stands up very well.

[17] UCAS UNDERGRADUATE COURSE SEARCH. *Computer Aided Product Design courses in the United Kingdom 1999/2000.* UK. <http:/www.ucas.ac.uk> accessed 16/03/2000.

	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/2000
Target No	12	20	40	40	75	75	60	60	40	40	60
Enrolled	26	39	40	43	82	66	72	52	41	42	59
Difference	14	19	0	3	7	-9	12	-8	1	2	-1

Table 2.1 BSc CAPD Enrolment Figures for 1989-1999

2.3 The BSc Computer Aided Product Design (CAPD) Course, University Of Wolverhampton

The BSc (Hon's) in Computer Aided Product Design, at the University of Wolverhampton is a joint venture between School of Engineering and the Built Environment, and the School of Art and Design (reference: - [18] Felton and Bird July 1998). The award was developed in response to criticism of design education in the UK in the late 1980's. This criticism suggested that an industrial designer could style a good looking product, but lacked an understanding of manufacture. On the other hand, the design engineer who was predominantly concerned with the technical function and manufacture lacked aesthetic awareness. In order to educate a new breed of designer, the BSc in Computer Aided Product Design Award was devised as a hybrid course which, in 1989, was in the vanguard of a new wave of product design initiatives in the HE sector that had a multidisciplinary approach. It aimed at producing what was then a new type of product design graduate who could combine the skills and theoretical knowledge of an engineer with the conceptual ideas of the industrial designer. The course aimed at producing a designer with a richer blend of skills who did not just produce ideas and concepts that were passed on to the production and manufacturing engineers who sorted out the problems for production, but one who could work from both ends of the design and manufacturing spectrum, i.e. be able to produce conceptual design and have the technical knowledge to liaise with the production and manufacturing specialist.

2.3.1 Background To The Course

Development of the BSc CAPD course took place during 1988/89 following research,

[18] FELTON, A. J., BIRD, E. Computer Aided Product Design - An Exercise in Institutional and Industrial Integration at Wolverhampton. PDE98 Conference, University of Glamorgan, 6th-7th July 1998.

references - [19]*Training Designers For The 1990's* (1983), [20]Ewing (1987), European Initiatives through the ERASMUS/COMETT programme and feedback from Industry. It was ascertained that a new type of designer was required who could combine the skills and theoretical knowledge of an engineer and the conceptual ideas of the industrial designer. The degree programme was based on this premise. The aim was to move away from what was loosely termed by the design team as "Over the wall design" i.e. the designer who produced concept designs and passed them on to the production / manufacturing engineers to sort out and produce. What was required was a designer who could work at both ends of the design spectrum, be able to produce design concepts but also have the technical knowledge to communicate and liaise effectively with manufacturing, materials and production engineers to achieve the product goal.

The new BSc CAPD graduate would have a broad range of transferable skills to enter the new and fast changing job market of the 1990's that did not offer a traditional career for life, but required flexibility, adaptability and team participation.

Within the institution industrial design had been traditionally offered within the School of Art and Design (SAD), while traditional mechanical and production engineering had been offered in the School of Engineering and the Built Environment (SEBE). The new course needed to offer a richer blend of skills between Industrial Design as then offered in the Three Dimensional Design Subject area of the School of Art and Design at Wolverhampton and traditional Mechanical Engineering offered in the School of Engineering and the Built Environment (SEBE). The new BSc CAPD course transcended traditional institutional

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[19] *Training Designers For The 1990's*. (23rd Nov 1983) Heads of Industrial Design Conference Report, Royal Institution London:The Design Council.

[20] EWING, Paul.D. Author, (1987) *Curriculum Development Report On Industrial Design Engineering*, London: The Design Council.

boundaries and was one of the first close collaborative ventures between schools within the institution and aimed to bring together a blend of skills in design, engineering, manufacturing and computing.

2.3.2 Aims And Philosophy Of The Course

Reference [21]Course Guide (1993/94) pp. 2-15. The course aims to produce a broad-based educational programme of study in the creative, technical and commercial aspects of Product Design. The essential skills of a designer are developed through a balanced blend of creativity, analysis, synthesis and judgement. Strong emphasis is placed upon modern high technology aids to design, particularly in the use of advanced computer graphics facilities.

The course in its development stage recognised the growing importance of an international dimension and in particular design within a European context. An important aspect of the course was a strong European emphasis, clearly expressed in the intention to foster and encourage student mobility and exchange with European partner institutions. To facilitate this, the course offered students the opportunity to study a foreign language of their choice and to experience study periods in a European country.

The curriculum has been developed to educate graduates with a broad based knowledge of design together with an understanding of engineering science, materials, manufacturing processes and business. These discipline areas are integrated through the vehicle of design

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[21] *Course Guide, BSc/BSc Hon's Computer Aided Product Design (1993/94).* University of Wolverhampton, School of Engineering and the Built Environment, England. pp. 2-15.

computing to involve modern aids to creativity and professional design practice within a high technology environment.

The course has been developed from a central programme of studies, which formed the core of Product Design. A complementary programme was originally offered at Level I (year 1) and Level II (year 2) and provided the opportunity to study either Business Studies, Languages, or Art and Design Studies. Students would normally elect to follow one of these options at Level I and continue the study into Level II. The offering of the modules was subject to any prevailing conditions applied to the modules. The first year of the course comprised a high proportion of modules currently available on a range of other programmes of study. This commonality provided the necessary flexibility for student transfer to, and from, this programme to related programmes.

2.3.2.1 Aims

The aims of the course are to:

- provide an education in the field of Product Design,
- foster an appreciation and understanding of the many aspects of design requirements,
- develop the ability to practice design with a multi-disciplinary environment and in a highly competitive market,
- develop competence and confidence in an environment of rapidly evolving technology.

The aims of the course are achieved within the course structure through the integrative philosophy adopted both within subject disciplines and across subject disciplines. These aims are supported by a series of specific detailed objectives that provide the broad base foundation of the course and facilitate the integrative philosophy.

2.3.2.2 Course Objectives

The course objectives are to: -

- develop the ability to make accurate, reasoned and informed judgements in the specification, selection and development of design solutions,
- evaluate problems and determine appropriate solutions by systematic analysis and logical approach,
- develop a sense of creativity, innovation and enterprise,
- relate aesthetic, human factors, social and environmental criteria used in determining the design of products to the aspects of functionality, customer satisfaction, viability and market acceptance,
- be able to develop and sustain levels of design ability commensurate with professional competence,
- instil skills of communication and inter-personnel liaison in the industrial/business environment,
- develop an awareness of the technical, commercial and social factors in the management of the design process,
- develop confidence and competence in the skills of design computing,
- encourage the use of innovative ideas in the solution of design problems,
- provide knowledge and experience of necessary skills in the use of computer aids in design,

- improve product design skills by the utilisation of new technology,
- develop an understanding of the techniques for more effective management of design,
- instil an appreciation of the impact of design decisions on company profitability.

2.3.2.3 Curriculum Structure

According to the [22]'Retrospective Review' document (1991/96) pp.4-5 the award was validated in 1989 and reviewed in 1991 and brought into line with the other awards in the Faculty with a five-year validation period. Each year since then, minor changes have been made to the award to improve the quality of the learning experience for the students. In 1992/93 the module CM 1108 'Computer Aided Engineering' was introduced as an alternative to 'Introduction to Information Technology' also the ability to offer a full-time option instead of a sandwich only award. Further minor options were introduced in 1993/94.

The course was devised around a central study programme in the major discipline areas within and contributing to the field of Product Design. This was complemented by the provision of a parallel study programme developed to "open up" the course to a richer blend of study. At this initial phase of course development, students were invited to elect a course of study from one of the following: -

- University languages programme
- University business studies programme
- Art and Design studies programme.

[22] *Retrospective Review,* document. (1991/96) University of Wolverhampton, School of Engineering and the Built Environment, Engineering Division, England. pp.4-5.

The diagram Fig 2.8 shows the layout of the course programme (1992/94) and the progression of study through each semester. The prescribed programme of study had been developed on a progressive structure, establishing a foundation of study in Year 1 and developing and integrating the subject disciplines through the later semesters.

The course may be completed in either 3-Year Full Time or 4-Year Sandwich mode. All students are enrolled initially onto the 4-Year Sandwich degree. However, students may during Year 2 opt to transfer to the 3-Year Full Time Award.

The first year of the course was developed as a diagnostic year, identifying and compensating for differences in student background and establishing the foundations of study in Product Design.

Each module counts for 15 credits, all Semesters have a total of 4 modules (60) credits.

The Level II studies extend the foundation work, consider the concepts, tools and methodology and begin the introduction of the student to the 'integrative applications' dictated environment of design. Level II studies have a steadily increasing emphasis upon student centred activity, reflecting the growing experience of the students and the need to permit opportunities for free expression of ideas.

The final year of the course places a great emphasis upon both individual and group working to evolve ideas and solutions to design problem situations. The year balances the need for meaningful experience in design application with the requirements of an understanding of the managerial aspects of the design process and the responsibilities and commitment of the designer both in a technical and social capacity. The project is a major component of Level III studies and carries the equivalent of three full modules of credits. The conduct of the project has been broken down into two sections, a planning phase in

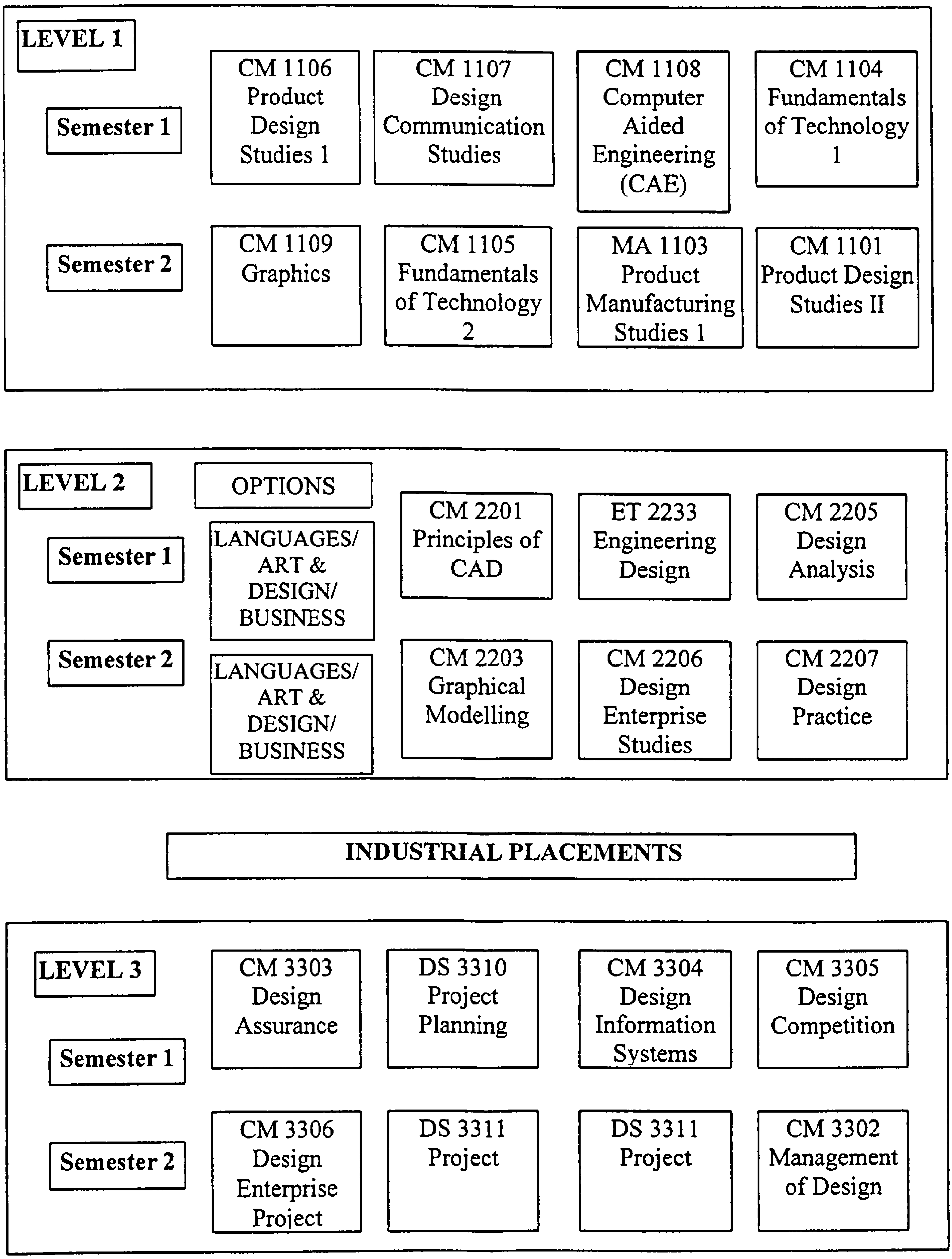

Fig 2.8 BSc (Hon's) Computer Aided Product Design (1992/94)

Semester 5 followed by a double rated module in Semester 6 for the major part of implementation. Students select their specific project prior to the commencement of Semester 5 and are allocated an appropriate supervisor. During the planning period regular contact is maintained between student and supervisor to discuss the progress and the development of the design brief. Student performance is assessed at the end of the semester on the basis of a written design brief for the project, detailed planning charts and work programmes, specification of resource requirements, strategy for procurement, presentation boards and model.

2.3.2.4 Modified Curriculum

Since the award was validated in 1989 and reviewed in 1991 minor revisions have been made every year to keep the award at the forefront of advanced technology and to improve the quality of the learning experience for the students.

The major criticism by students in the earlier years of the course was the lack of computing applications in the first year. This was addressed, as mentioned above, by introducing the module 'Computer Aided Engineering' as an alternative to 'Introduction to Information Technology' in the first semester and introducing the use of software applications into five other first year modules.

The award, as originally designed, was basically a prescribed one, in that there were only two modules, in the second year, made available as options. The choice was extended in 1994/95 by arranging two module options in year 1 and two module options in year 2 providing five additional named options in 1995 and 'Consumer Electronics' was added to the options list in 1996. Previous to this some students had commented that the first year still lacked enough CAD experience, the introduction of a full set of options including CAD during the next session would help to satisfy those students who required this emphasis to the course.

By October 1996 the BSc Computer Aided Product Design course offered new students six specialist option routes in years 1 and 2 of the course with a common final year. The idea was to allow students more flexibility and the opportunity to select a specialist route in a vocational area for future employment. Reference Appendix V gives a full listing of options and modules available, these options included: -

i) Industrial Design

ii) Computer Aided Design (CAD)

iii) Consumer Electronics

iv) Languages

v) Business Studies

vi) Business Enterprise

The rationale behind the options was that although the award was unique at its inception there were more and more courses of a similar nature being developed around the country. In order to meet the increased competition, the award team developed the option choices that were validated in order to enhance the appeal of the award to prospective students.

With reference to the University of Wolverhampton BSc CAPD document [[23] (May 1996) p6] the award team saw the addition of a 'Consumer Electronics' option as vital to its strategy of maintaining the attractiveness of the award. Most new products that are being

[23] *A proposal for the addition of a Consumer Electronics option to the award.* (May1996) University of Wolverhampton, School of Engineering and the Built Environment, Engineering Division, England. p.6.

currently developed involve electronics in some form. Even after excluding 'high tech' electronic equipment and consumer goods there are many simpler products that involve electronics to a greater or lesser degree.

It is important that the modern product designer is able to innovate products involving the use of electronics (rather than electronic products) and although all students at present undergo some electrical/electronics activity in module CM1105 Fundamentals of Technology 2, it represents less than one module. It was hoped that the successful implementation of this option would increase markedly the proportion of projects in this important area.

The new option choices have been explained at Open Days for prospective students and applicants advised that they would need to make a choice of option immediately the award commences. The Year Tutors and Award Leader interview each student during induction week (a major task but a beneficial one) to give individual advice on the options. However, over the two years the six options were in place approximately 49% of students selected BSc CAPD (Industrial Design Option) another 49% the BSc CAPD (CAD option) route with low numbers 1% or 2% opting for Consumer Electronics, Business Studies or Languages. Because of the low number of students requesting these specialized options and the staffing costs for such low numbers the course team decided to suspend these and concentrate on the more popular BSc CAPD course and the BSc Computer Aided Industrial Design option within this programme.

Since 1998/1999 however, first year enrolment numbers have shown the majority of students now selecting the BSc CAPD course as shown in Fig 2.9 (essentially the CAD option) with just a few requesting Industrial Design.

LEVEL 1

Semester 1	*CM 1004 CAD Fundamentals*	MA 1103 Product Manufacturing Studies 1	CM 1003 Computer Aided Communications	CM 1000 Product Design and Development
Semester 2	*CM 1001 CAD Applications*	CM 1105 Fundamentals of Technology 2	CM 1104 Fundamentals of Technology 1	CM 1109 Graphics

LEVEL 2

Semester 1	*CM 2203 Graphical Modelling*	DS 2229 Design Principles	CM2002 Engineering Design	CM 2205 Design Analysis
Semester 2	*CM2000 Advanced Modelling*	DS 2228 3D Realisation	CM 2206 Design Enterprise Studies	CM 2207 Design Practice

INDUSTRIAL PLACEMENTS

LEVEL 3

Semester 1	CM 3303 Design Assurance	CM 3302 Project Planning	CM 3304 Design Information Systems	CM 3305 Design Competition
Semester 2	CM 3306 Design Enterprise Project	CM 3003 Project	CM 3003 Project	CM 3302 Management of Design

Fig 2.9 BSc (Hon's) Computer Aided Product Design

2.3.2.5 Entry Qualifications

Minimum age of admission: normally 18 years.

Minimum qualifications for admission: normally one of the following:

a) Two passes at GCE 'A' level subjects plus three GCSE or GCE 'O' level passes, one of which must be Mathematics. (A pass in GCSE means grace C or above).

b) Three passes at GCE 'A' level subjects plus a pass in Mathematics at GCSE or GCE 'O' level.

c) A good BTEC National Certificate or Diploma with merit level passes in three Level III subjects and a pass in Mathematics at least to Level II.

d) Satisfactory completion of a full time foundation course in Art and Design of not less than one year's duration together with the equivalent of five GCSE or GCE 'O' level passes or four GCSE or GCE level passes including one at 'A' level. Mathematics must have been passed at GCSE or GCE 'O' level.

e) Satisfactory completion of a suitable Access course.

f) Any qualifications equivalent to the above.

Exceptional Entry is available to mature students without one of the above qualifications who may be admitted on the basis of experience or other evidence of their ability to benefit from the course following a successful interview with design staff.

The entry requirements have been deliberately kept broad to enable students from a variety of backgrounds to enter the course. Applicants must demonstrate, by examination results or otherwise, a suitable proficiency in the English language.

All overseas applicants whose first language is not English must produce evidence that their command of the English language is such that they will be able to benefit from the course.

2.3.2.6 Access Courses

The course team recognised that many good practising designers did not gain their positions through the conventional higher education route and that the intellectual skills necessary for a good designer are not necessarily those assessed by the normal 'A' level examination. In addition, it was recognised that for a variety of reasons, ranging from lack of opportunity or guidance to boredom at school, some adults have obtained few or no qualifications yet have the potential to become good product designers. Thus the course team sees the Access Course as a valid and suitable entry route into the proposed course. To this end, any of the established Access Courses within the "Black Country Access Federation" which currently lead to entry into University Science, Business Studies or Craft Design Technology courses would be acceptable, subject to the proviso of a satisfactory interview.

2.3.3 Learning And Teaching

In the first study week, students receive a Module Guide for each module studied. This contains the Learning Outcomes, linked to the assessment procedures, a week-by week breakdown of subject matter, and the teaching and learning strategies. It should therefore be clear to the student what they should gain from the module, how they should gain it and how they will be assessed on it.

A wide range of teaching and learning strategies is employed and the balance between them is varied between modules to suit the nature of the subject. With reference to [24]'Review and Validation ' 1991-1997 p.105 document: -

The Engineering Subject area does not have a common strategy for an assessment regime, for example, examination 70% and coursework 30%, which has been common in some Subject areas in the past. The reason for this is the wide range of types of modules run by the Design Subject area. For example, Engineering Drawing does not lend itself to assessment by examination and neither do most forms of Computer Aided Design. It is generally considered that these type of topics are best assessed by assignment work. On the other hand there are other modules, such as 'Engineering Analysis' which because of their large numerical problem solving content do lend themselves to a formal examination, and in fact some would argue that some sort of assessment under controlled conditions is essential for this type of subject

Where modules do use an examination (which generally varies between 50 to 70% of the total grade) there is usually some assignment or practical work that gives the opportunity to assess module content which does not lend itself to formal examination. It also gives the opportunity for students whom for whatever reasons do not perform well in examinations, to show their ability in other directions and thus raise their overall grade.

Modules in the Computer Added Design area, in particular, have a predominance of assignment work as this is considered the best method of assessing both design and computer based modules.

[24] *Review and Validation,* document. (1991-1997) University of Wolverhampton, School of Engineering and the Built Environment, Engineering Division, England. p.105.

Whatever the type of module assessment regime, the Subject Leader attempts to maintain parity of workload and standard by limiting the number of 'elements' in the assessment package of all modules.

2.3.3.1 Learning Outcomes

In conformance with the University of Wolverhampton policy, the complete portfolio of module descriptions for the BSc CAPD course has been re-written in learning outcomes form, as laid down in the University of Wolverhampton document [25]'Design for Learning' (1996/97). As an example of modules written in this format just one of these is included in Appendix II, title of module "CM1000 Product Design and Development" page 1 - 4, for reference.

A simple definition of 'learning outcomes' is 'what the student should be able to do at the end of the module'. The Model 'B' format has been adopted by the Engineering Division, this format requires that the 'learning outcomes' be specified in three categories as given below.

a) Subject Specific Outcomes (SSO)

b) Personal Transferable Skills (PTS)

c) Generic Academic Outcomes (GAO)

a) Subject Specific Outcomes (SSO)

Subject Specific Outcomes define the subject. These are the abilities, knowledge and skills that relate directly to the module syllabus content and, except for minor overlap, should not

[25] *Design for Learning.* (1996/97) University of Wolverhampton, England. Section 'Model B'

be duplicated in any other module. The 'Subject Specific Outcomes' for each module normally conform to the three outcomes per module recommended, but sometimes, because of the nature of the module content, either four or only two outcomes have been specified. As outside bodies, particularly accrediting institutions, may be unused to a learning outcome approach, the full week-by-week syllabus has been given for every appropriate module so that the content may be reviewed in a more conventional style.

b) Personal Transferable Skills (PTS)

These are the skills that may be acquired through study of the module that are not subject specific and can be utilised either in other fields or in general employment. The 'Personal Transferable Skills' have been drawn from the standard list specified in the University of Wolverhampton 'Design for Learning' (1996/97) document and for convenience they are reproduced below.

It could be said that many of these transferable skills can be acquired in some degree from most modules, but only the two or three most important skills have been defined in each module.

Each Personal Transferable Skill is not assessed separately from the other outcomes but has been matched to specific assignment/s. For example, if a component of assessment requires a written assignment and this is linked to the ability to 'communicate effectively', then should a 'D5' (i.e. the lowest pass grade) or greater be achieved the student will automatically be deemed to have achieved that transferable skill.

PERSONAL TRANSFERABLE SKILLS

The ability to:

1. **Communicate effectively**

i *Writing skills*:- write accurately and effectively in a variety of structured formats (e.g. essay, reports, instructions), and demonstrate the appropriate conventions in each. Recognise different audiences and demonstrate use of appropriate writing styles, and relate these to appropriate audiences.

ii *Oral presentation skills*:- give, present material in a variety of structured formats (e.g. formal presentations, formal and informal explanations, instructions). Recognise different audiences and make use of appropriate styles, including interactive responses.

2. Organise

Identify and use existing resources effectively; develop flexibility in approaches to the management of work in hand. Recognise task demands and manage time effectively. Monitor, review and reflect upon self-management.

3. Gather Information

Gather information (archival and library material, data, statistics) and develop effective storage and retrieval systems. Interpret, analyse and synthesise material in a variety of forms (statistical or textual data, in an appropriate context)

4. Use Information Technology

Create, store and retrieve data in a variety of forms (word-processing, e-mail, databases, and spreadsheet graphics). Make effective use of information from a variety of sources e.g. CD-ROM, JANET, and Internet.

5. Act Independently

Develop autonomy, initiative, self-motivation and resourcefulness; demonstrate decision making and problem solving skills. Assess progress, and monitor, review and reflect upon own performance and achievements.

6. Work in Teams

Work co-operatively in-groups, share decision-making and negotiate with others. Awareness and the ability to adopt a variety of roles. Listen to relevant opinions before reaching decisions and relate the ideas of others to the task in hand. Evaluate the strengths and weaknesses of group effectiveness and of own performance within it.

7. Numeracy

Process numerical information related to real-life problems and interpret the outcomes. Develop sufficient symbolic and vocabulary skills to express and interpret a variety of coded statements.

c) Generic Academic Outcomes (GAO)

The 'Generic Academic Outcomes' relate to a more general expectation of the areas in which a student might be competent, having studied an award or 'subject' in a certain discipline. For instance any Engineering graduate should have some knowledge and understanding of engineering software (over and above general IT skills) although this may be different for a 'Product Designer' compared to a 'Manufacturing Engineer'. Thus competence in a particular piece of software, in addition to contributing to subject specific outcomes related to that module, also contributes to a more general outcome in the student's overall study of the engineering discipline. The 'Generic Academic Outcomes' can also be related to the academic 'level' of study and give the opportunity to ensure that there is a reasonable spread of such outcomes in a student's overall programme, e.g. a student taking 'Product Design' should have a strong emphasis on the outcomes "Think

Creatively" and "Make use of Applications Software" and perhaps less so on "Synthesise ideas and Information".

The 'Generic Academic Outcomes' for the Engineering Subject area are also reproduced below for convenience. Each 'General Academic Outcome' in the list from A to F attempts to define what would be the expected outcome at each level.

ENGINEERING GENERIC ACADEMIC OUTCOME/CRITERIA

A. MAKE USE OF APPLICATIONS SOFTWARE

LEVEL 1: Utilisation of basic engineering IT.

LEVEL 2: Use of commercial level software.

LEVEL 3: Use and customise Engineering software.

LEVEL 4: Apply and manipulate advanced Engineering software.

B. MAKE USE OF TECHNICAL INFORMATION

LEVEL 1: Supplement lecture notes by use of library/learning centre resources.

LEVEL 2: Select and use relevant references and quotation to support points being proposed.

LEVEL 3: Use specialist texts and journals to substantiate arguments: collate material from a variety of sources into a coherent argument.

LEVEL 4: Critically review Engineering concepts.

C: EVALUATE AND APPRAISE

LEVEL 1: Apply standard procedures to given situations.

LEVEL 2: Select an appropriate solution from a limited range of possibilities.

LEVEL 3: identify solution methodologies and justify selection.

LEVEL 4: Produce solution criteria and optimise.

D: ANALYSE

LEVEL 1: Identify ideas, concepts and apply standard theories.

LEVEL 2: Compare alternative procedures and apply appropriate solutions.

LEVEL 3: Analyse Engineering problems using a multifaceted approach.

LEVEL 4: Develop optimum solutions to open-ended problems.

E: SYNTHESISE IDEAS AND INFORMATION

LEVEL 1: N/A

LEVEL 2: Relate theoretical ideas to practical tasks.

LEVEL 3: Integrate learning from different sources.

LEVEL 4: Incorporate theoretical and practical theories into novel scenarios.

F: THINK CREATIVELY

LEVEL 1: Solve Engineering problems with limited solutions.

LEVEL 2: Create solutions to Engineering problems with specified technical constraints

LEVEL 3: Provide innovative solutions to diverse problems.

LEVEL 4: Provide professional standard solutions to commercial problems.

The three main academic levels of modules offered on undergraduate awards at the University of Wolverhampton correspond to the three years of a normal full-time undergraduate course. As there are many modes of attendance and delivery mechanisms to which the same module may be delivered it is more appropriate to talk in terms of a level rather than a year. The levels are defined as follows:

Level 1 modules are equivalent to year 1 of a full-time course. Their characteristics include providing an orientation or balancing phase for students entering Higher Education from a variety of different qualifications, experiences and backgrounds as well as introducing students to the character and activities of a subject and to the basic methodologies and concepts required for subsequent study in the subject. Some of these modules may have other level 1 modules as pre-requisites. Normally a level 1 module will be a pre-requisite for a level 2 module.

Level 2 modules are equivalent to year 2 of a full-time course and are concerned with developing the student's intellectual and imaginative powers, understanding, judgement and problem solving skills as well as a deepening awareness and knowledge of their discipline.

Level 3 modules are equivalent to year 3 on a full-time course and offer the opportunity of greater breadth or depth in a subject with a particular emphasis on the development of independent thought and judgement, the synthesis of issues of increasing complexity or more sophisticated conceptualisation.

Modules to be delivered on 'Masters' awards then follow logically as level 4.

Level 4 modules are equivalent to the one year of a full-time 'Masters' course and are exemplified by the depth and specialism of the subject matter and also by the professional standard of the accomplishment required.

2.3.3.2 Assessment

The purpose of the assessment scheme is: -

(i) To provide a measure of the extent to which students have satisfied the aims and objectives of the course.

(ii) To ensure the compatibility of standards with other degree courses both within and outside the University.

The module guides students receive specify the number and types of assessment together with the relative weighting used to arrive at the overall grade for the module. The final grades for the modules are expressed using the 'Common Grade Point Scale' as laid down by the University of Wolverhampton, reference [26]'University Academic Regulations' (1997/98). These are reproduced on the following page: -

[26] *University Academic Regulations.* (1997/98) University of Wolverhampton, England.

DEFINITION OF GRADES AS APPLIED IN THE ENGINEERING DIVISION

Grade Point Scale	Description (Honors Equivalent)
A16, A15, A14	**Outstanding Performance (First).** Outstanding ability to solve engineering and design related problems, and interrelate concepts. ideas and theories with practice and applications. Cogent and sustained justification of solutions and strategies adopted. Considerable evidence of independent thought. Perceptive and skilled use of sources of information. Exceptional appreciation of the engineering dimension.
B13, B12, B11	**Above Average (Upper Second).** Good ability to solve engineering and design related problems, and interrelate concepts ideas and theories with practice and applications. Coherent justification of solutions and strategies adopted. Effective use of sources of information. Good appreciation of the engineering dimension.
C10, C9, C8	**Average Performance (Lower Second).** A reasonable ability to solve engineering and design related problems ad a sensible relationship established between theories practice and applications. Organised justification of solutions and strategies adopted. Adequate use of sources of information. Reasonable appreciation of the engineering dimension.
D7, D6, D5	**Satisfactory Performance (Third).** Limited but sufficient ability to solve engineering and design related` problems. Satisfactory but restricted ability to develop relationships established between theories, practice and applications. Adequate justification, but shows incomplete realisation of the implications of solutions and strategies adopted. Use of sources of information satisfactory but restricted. Limited appreciation of the engineering dimension.
E4, E3	**Marginal Fail.** Insufficient understanding of the processes required to solve engineering and design related problems effectively. Weak ability to develop relationships established between theories, practice and applications. Inadequate justification of solutions and strategies adopted showing little realisation of the implications. Use of sources of information unsatisfactory. Restricted` appreciation of the engineering dimension.
F2, F1	**Fail.** Little understanding of the processes required to \solve engineering and design related problems effectively. Relationships between theory, practice and applications weakly developed. Incoherent justification of solutions and strategies adopted. Poor use of sources of information. Little appreciation of the engineering dimension.
F0	No Assessment

2.3.4 An Integrated Approach To Curriculum Development

[27]Felton and Bird (September 1998) conference paper discusses the development of an Integrated approach to curriculum development in product design based upon the BSc CAPD course. Integration is the key word both for students and the programme, which is drawn from expertise across the two schools and offers the broad range of inter-related skills outlined in Fig 2.10 for the BSc CAPD (CAD Option) and Fig 2.11 BSc CAPD (Industrial Design Option). Four main skill areas were identified: -

i) **Design Awareness and Visual Communication** supported by Product Design Staff from the SAD.

ii) **Engineering Design** supported by Mechanical Engineering staff from the Engineering Division of SEBE.

iii) **Manufacturing and Technology** supported by Manufacturing Staff from the SEBE.

iv) **Computing and Information Technology** supported by Design engineering staff from SEBE.

The other integrating vehicle for these skills is the practical design projects that occur in each level (year) of the course and have multi-staff supervision. These projects increase in complexity with each level and range from being introductory and diagnostic at level 1 to a comprehensive test of all the skills outlined at level 3, where students undertake a self initiated project that occupies the final half of their completing year.

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[27] FELTON, A. J., BIRD, E. *Developing An Integrated Approach With Undergraduate Product Design Students.* 14th National Conference on Manufacture Research, University of Derby, UK. 7th-9th September 98, pp. 603-608.

1. Design Awareness and Visual Presentation Skills.	2. Engineering Design Skills	3. Manufacturing and Technology Skills	4. Computing and IT Skills	5. Design Projects. Testing of Skill Areas 1,2,3 and 4
<u>LEVEL 1 (First Year)</u> **CM1000 Product Design and Development.** Aesthetics, Design Methodology, Anthropometrics, Ergonomics. **CM1109 Graphics** Introduction to visual presentations skills both manually and via computer.	**CM1003 Computer Aided Communications.** Mathematical skills and Eng IT **CM1004 CAD Fund's. & CM1001 CAD Applications** 2D CAD skills in an industrial environment.	**MA1103 Product Manufacturing Studies.** Introduction to manufacturing processes. **CM1104 & CM1105 Fundamentals of Technology 1& 2** Eng principles, Mat'ls, Electric's and Electronics.	**CM1003 Computer Aided Communications.** Mathematical skills and Eng IT **CM1004 CAD Fund's. & CM1001 CAD Applications** 2D CAD skills in an industrial environment.	**CM1000 Product Design and Development.** Theory and practice of a design project. Students tackle their first design project alongside a series of lectures which take them through the design process.
<u>LEVEL 2 (Second Year)</u> **DS2229 Design Principles.** Development of visual presentation skills through assignments. **DS2228 3D Realisation.** Development of model making skills.	**CM2002 Engineering Design.** Technical aspects of designing Engineering Products. **CM2206 Design Enterprise Studies.** Design in a company structure, economics, marketing.	**CM2205 Design Analysis.** Analytical methods for product component strength including Finite Element.	**CM2203 Graphical Modelling.** Extends CAD experience into 3D forms. **CM2000 Advanced Modelling.** Design for manufacture, 3D Feature modelling, Rapid Prototyping, Concurrent Engineering.	**CM2207 Design Practice.** Practical experience of the Design Process with a group Design and Make Project.
<u>LEVEL 3 (Third Year)</u>	**OPTIONAL**	**INDUSTRIAL**	**PLACEMENT**	**YEAR**
<u>LEVEL 3/4 (Final Year)</u> **3rd Year direct course for students, or 4th Year students returning from Industrial Placements.**	**CM3302 Management Design.** Factors involved in managing design in an engineering context.	**CM3303 Design Assurance.** Quality Control in the Design and Manufacturing process.	**CM3304 Design Information Systems.** CAD Technology in the design context. **CM3306 Design Enterprise project.** Students work in teams and set up a company to manufacture a product.	**DS3310 Project Planning.** Planning process for the final Design Project modules. **DS3311 Design Project.** Double module, individual final project. **CM3305 Design Competition.** The experience of entering an actual design competition.

Fig 2.10 BSc (Hon's) Computer Aided Product Design (CAD Option) Curriculum (Inter-related skills)

1. Design Awareness and Visual Presentation Skills.	2. Engineering Design Skills	3. Manufacturing and Technology Skills	4. Computing and IT Skills	5. Design Projects. Testing of Skill Areas 1,2,3 and 4
<u>LEVEL 1 (First Year)</u> **CM1000 Product Design and Development.** Aesthetics, Design Methodology, Anthropometrics, Ergonomics. **CM1109 Graphics** Introduction to visual presentations skills both manually and via computer.	**CM1003 Computer Aided Communications.** Mathematical skills and Eng IT **CM1004 CAD Fund's. & CM1001 CAD Applications** 2D CAD skills in an industrial environment.	**MA1103 Product Manufacturing Studies.** Introduction to manufacturing processes. **CM1104 & CM1105 Fundamentals of Technology 1& 2** Eng principles, Mat'ls, Electric's and Electronics.	**CM1003 Computer Aided Communications.** Mathematical skills and Eng IT **CM1004 CAD Fund's. & CM1001 CAD Applications** 2D CAD skills in an industrial environment.	**CM1000 Product Design and Development.** Theory and practice of a design project. Students tackle their first design project alongside a series of lectures which take them through the design process.
<u>LEVEL 2 (Second Year)</u> **DS2229 Design Principles.** Development of visual presentation skills through assignments. **DS2228 3D Realisation.** Development of model making skills.	**CM2002 Engineering Design.** Technical aspects of designing Engineering Products. **CM2206 Design Enterprise Studies.** Design in a company structure, economics, marketing.	**CM2205 Design Analysis.** Analytical methods for product component strength including Finite Element.	**CM2203 Graphical Modelling.** Extends CAD experience into 3D forms. **CM2000 Advanced Modelling.** Design for manufacture, 3D Feature modelling, Rapid Prototyping, Concurrent Engineering.	**CM2207 Design Practice.** Practical experience of the Design Process with a group Design and Make Project.
<u>LEVEL 3 (Third Year)</u>	OPTIONAL	INDUSTRIAL	PLACEMENT	YEAR
<u>LEVEL 3/4 (Final Year)</u> **3rd Year direct course for students, or 4th Year students returning from Industrial Placements.**	**CM3302 Management Design.** Factors involved in managing design in an engineering context.	**CM3303 Design Assurance.** Quality Control in the Design and Manufacturing process.	**CM3304 Design Information Systems.** CAD Technology in the design context. **CM3306 Design Enterprise project.** Students work in teams and set up a company to manufacture a product.	**DS3310 Project Planning.** Planning process for the final Design Project modules. **DS3311 Design Project.** Double module, individual final project. **CM3305 Design Competition.** The experience of entering an actual design competition.

Fig 2.10 BSc (Hon's) Computer Aided Product Design (CAD Option) Curriculum (Inter-related skills)

1. Design Awareness and Visual Presentation Skills.	2. Engineering Design Skills	3. Manufacturing and Technology Skills	4. Computing and IT Skills	5. Design Projects. Testing of Skill Areas 1,2,3 and 4
LEVEL 1 (First Year) **CM 1106 Product Design Studies 1** Design Awareness **CM1109 Graphics** Introduction to visual presentations skills both manually and via computer.	**CM1107 Design Communication Studies.** Introduction to numeracy and technical drawing skills in an engineering context.	**MA1103 Product Manufacturing Studies.** Introduction to manufacturing processes. **CM1104 & CM1105 Fundamentals of Technology 1& 2** Eng principles, Mat'ls, Electric's and Electronics.	**CM1108 Computer Aided Engineering.** Introduction it to information technology in an engineering context.	**CM1101 Product Design Studies 2.** Theory and practice of a design project. Students tackle their first design project alongside a series of lectures which take them through the design process.
LEVEL 2 (Second Year) **DS2229 Design Principles.** Development of visual presentation skills through assignments. **DS2228 3D Realisation.** Development of model making skills.	**CM2002 Engineering Design.** Technical aspects of designing Engineering Products. **CM2206 Design Enterprise Studies.** Design in a company structure, economics, marketing.	**CM2205 Design Analysis.** Analytical methods for product component strength including Finite Element.	**CM2201 Principles of CAD.** Introduction to the principles of computer aided design 2D form. **CM2203 Graphical Modeling.** Extends CAD experience into 3D forms.	**CM2207 Design Practice.** Practical experience of the Design Process with agroup Design and Make Project.
LEVEL 3 (Third Year)	**OPTIONAL**	**INDUSTRIAL**	**PLACEMENT**	**YEAR**
LEVEL 3/4 (Final Year) **3rd Year direct course for students, or 4th Year students returning from Industrial Placements.**	**CM3302 Management Design.** Factors involved in managing design in an engineering context.	**CM3303 Design Assurance.** Quality Control in the Design and Manufacturing process.	**CM3304 Design Information Systems.** CAD Technology in the design context. **CM3306 Design Enterprise project.** Students work in teams and set up a company to manufacture a product.	**DS3310 Project Planning.** Planning process for the final Design Project modules. **DS3311 Design Project.** Double module, individual final project. **CM3305 Design Competition.** The experience of entering an actual design competition.

Fig 2.11 BSc (Hon's) Computer Aided Product Design (Industrial Design Option) Curriculum (Inter-related skills)

The curriculum also has to take into account the broad educational background from which the course recruited. Recruitment includes students from art and design as well as technological and computing backgrounds, students come directly from school at sixth form level, from Further Education colleges through to mature students from access courses. Student profiles entering the 1st year of the course are mixed; the intake includes 'A' Level students, students from Foundation courses in Art and Design, BTEC National, GNVQ and Access students. The prescribed programme of study has therefore been developed as a progressive structure, establishing a solid foundation of basic skills in Year 1 and then developing the subject disciplines through the subsequent semesters.

2.3.4.1 The Project Base Of BSc CAPD

At each level (year) of the course, projects have specific aims and develop aspects of the four core skill areas outlined above. At level 1 (year 1) the student skill level is diagnostic. At level 2 (year2) skills are developed while at level 3 (final year) they are tested in a professional design situation. Project modules are monitored and feedback supplied on a regular basis throughout the module, either by contact with individual project supervisors or on a group basis with regular project management group meetings at which students present a progress report.

The following uses three projects as examples of this approach at Level 1, Level 2 and Level 3.

2.3.4.2 Level 1, Year 1 Projects

The first year project occurs in either the module Product Design Studies II or Product Design and Development depending on the route the student has followed. The modules have an introductory design and make project which is diagnostic and supported with a series of lectures that introduce the main elements of practical design such as Aesthetics, Design Management, Morphology of Design, Design Specification, Design Protection, Ergonomics and Anthropometrics. It is diagnostic because of the broad intake of students on the course. With a differing range of prior experiences it intends to identify individual strengths and weaknesses that can be picked up on in Level 2. It also tests the student's knowledge accumulated from the other seven modules of study at Level 1. The project subject matter has varied over the years and has included: -

A mechanically powered toy.

A toy that flies.

Lifestyle projects for an ageing society.

Portable office for a designer on the move.

In flight airline meals tray.

A child's briefcase.

A retractable Modelling knife.

Kite Design.

Cardboard seat for summer outdoor concerts.

For many of the students it is their first attempt at a design brief and because of its diagnostic nature we are more interested in the process than the outcomes. The design brief is highly prescriptive and outlines in detail what is expected and the importance that we attach to the different elements through the marking scheme.

Using the Kite Design as an example the student is expected to research the project, in fact 25% of the marking is devoted to a research report, which is handed in six weeks into the project. This asks the student to thoroughly research the role of kites in eastern and western cultures from the point of view of materials and construction.

The project is extremely prescriptive regarding the work that has to be produced and each section is given a mark. The six sections of this project are: -

1. Comprehensive illustrated report (25 marks)
2. Preliminary design ideas explaining the design of your kite (15 marks)
3. Detailed technical drawing of the construction of your kite (10 marks)
4. Technical specification including materials and costing (10 marks)
5. Construction Leaflet to potential purchaser (10 marks)
6. Final Kite Scores. Quality and appeal of final solution (10 marks)
   Flying ability (20 marks)

Three major constraints are applied to the project:

- maximum cost of materials not to exceed £2
- Packaging of the kite to form part of the structure.
- The finished prototype must be tested and flown.

This project is ongoing through the semester and in a report students are expected to outline and relate design and manufacturing issues and account for the management of their time.

Plates 2.1 and 2.2 show two students design solutions for a recyclable cardboard seat for summer outdoor concerts (BSc CAPD Level 1, Product Design and Development module).

Plate 2.1 Recyclable cardboard seat for outdoor summer concerts. BSc CAPD Level 1, Product Design and Development module, Design and make project.

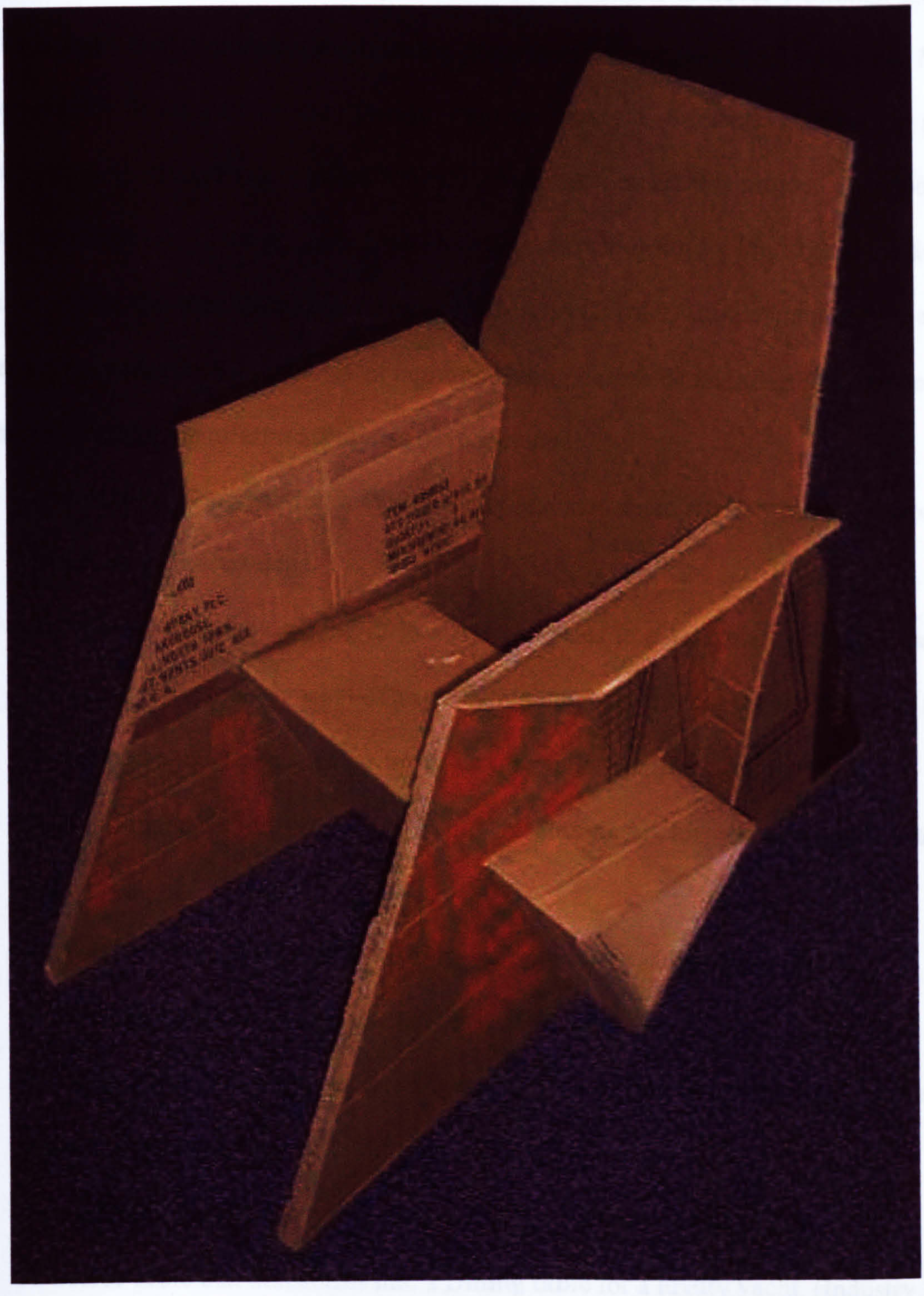


Plate 2.2 Recyclable cardboard seat for outdoor summer concerts, produced as a flat pack, and assembled on entry to the concert. BSc CAPD Level 1, Product Design and Development module, Design and make project.

2.3.4.3 Level 2, Year 2 Projects

Having had the opportunity to develop and rectify deficiencies at Level 1 through module feedback and Level 2 modules, the learning process is tested again in a Design and Make project which forms part of the 'Design Practice' module. Students working in pairs, working to their strengths as opposed to their weaknesses, tackle this project. Workload is shared for all aspects of the project. Each student takes responsibility for 50% of the design work however; the manufacturing responsibility is switched. This is intended to allow students to experience the problems of communicating design details to others responsible for their successful manufacture. Projects have included: -

A **device for transporting a Wind-surfer** and associated rig from the car, across a beach, to the waters edge.

A **cycle carrier** for carrying at least two bicycles in a safe manner which can be bolted to the tow bar bracket of a car, taking into account that the towball may need to be fitted at the same time for towing a caravan or camping trailer.

A small portable or hand held **Wind Anemometer** for yachting and outdoor activities.

A **Weight Lifting bench / Exercise bench.** (Industry sponsored project)

A **Folding chair** for the Leisure market.

A **Collapsible or folding carrier** for the caravan market to carry a gas cylinder or water container.

Telescopic Tree Pruners adjustable for working at elevated heights.

A **Coffee table** that transforms into a **Dining table** for a luxury yacht. (Industry sponsored project)

The project topic for this module a portable hand-held wind anemometer for an outdoor activity such as sailing or climbing is used as an example. The product was anticipated to retail at around £50 and the students were expected to produce details for packaging, usage, materials and methods for manufacture.

The students were presented with an action list that included a calendar of target dates for different levels with the work to be produced. Student teams were expected to produce a final working prototype by the 12th week of the project with the module being timetabled for a one day per week slot, each group then presented their designs and prototypes to their peers, highlighting good or bad design features and problems encountered. The two-member team worked extremely well and produced some highly professional solutions in what was a short period of time. The workload was demanding and all groups met the pre-set targets that were: -

Weeks 1-5	Initial design content and Research
	Responsibility action to each group member
	Preliminary CAD drawings
	Preliminary models
Week 6	Verbal and written progress report and design solutions
Week 10	Final 2D and 3D CAD drawings
Week 11	Hand in paperwork submissions
Week 12	Final presentation of solution and evaluations

Working in pairs meant that students contributed their best actions and learned from each other. The grouping also encouraged confidence and critical awareness and evaluation of each other's contributions. The best solutions worked well and were prototypes of commercially viable products.

As well as the manufactured artifact, a comprehensive project report is submitted by students, to include research, concept designs, dimensioned CAD working drawings, 3D CAD modelling including some aspect of Finite Element analysis, costing details, packaging, intended usage, materials selection and details of manufacture.

The following plates show a range of Level 2, BSc CAPD design and make projects.

Plate 2.3 Re-produced Replica Models. BSc CAPD Level 2, 3D Realisation module.

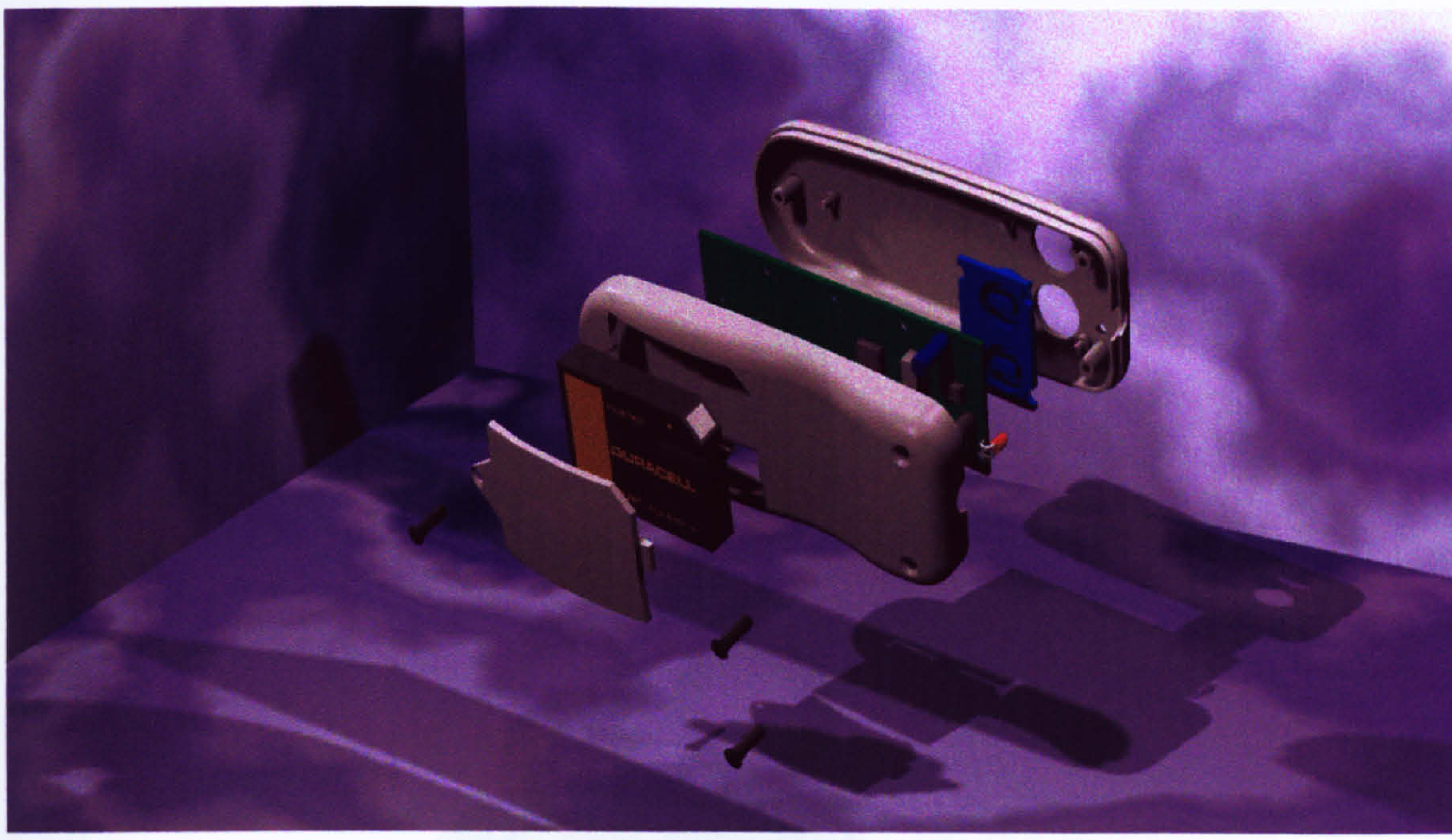


Plate 2.4 Remote Control For Stair Lift. Modelled in SolidWorks by Mark Downing
Level 2 BSc CAPD Design Principles module 1999/2000

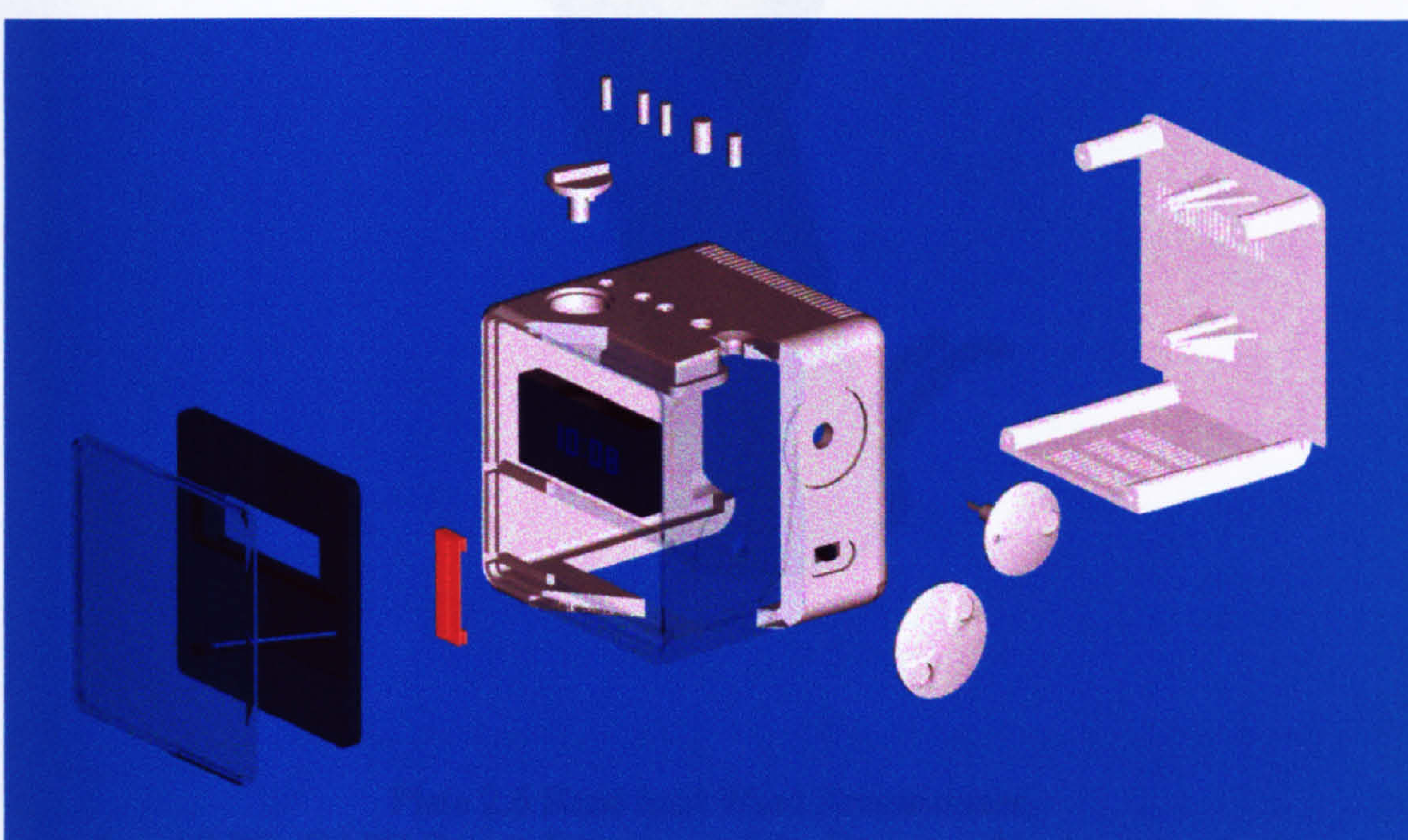


Plate 2.5 Exploded view of Digital Clock by Martin Wilcockson.

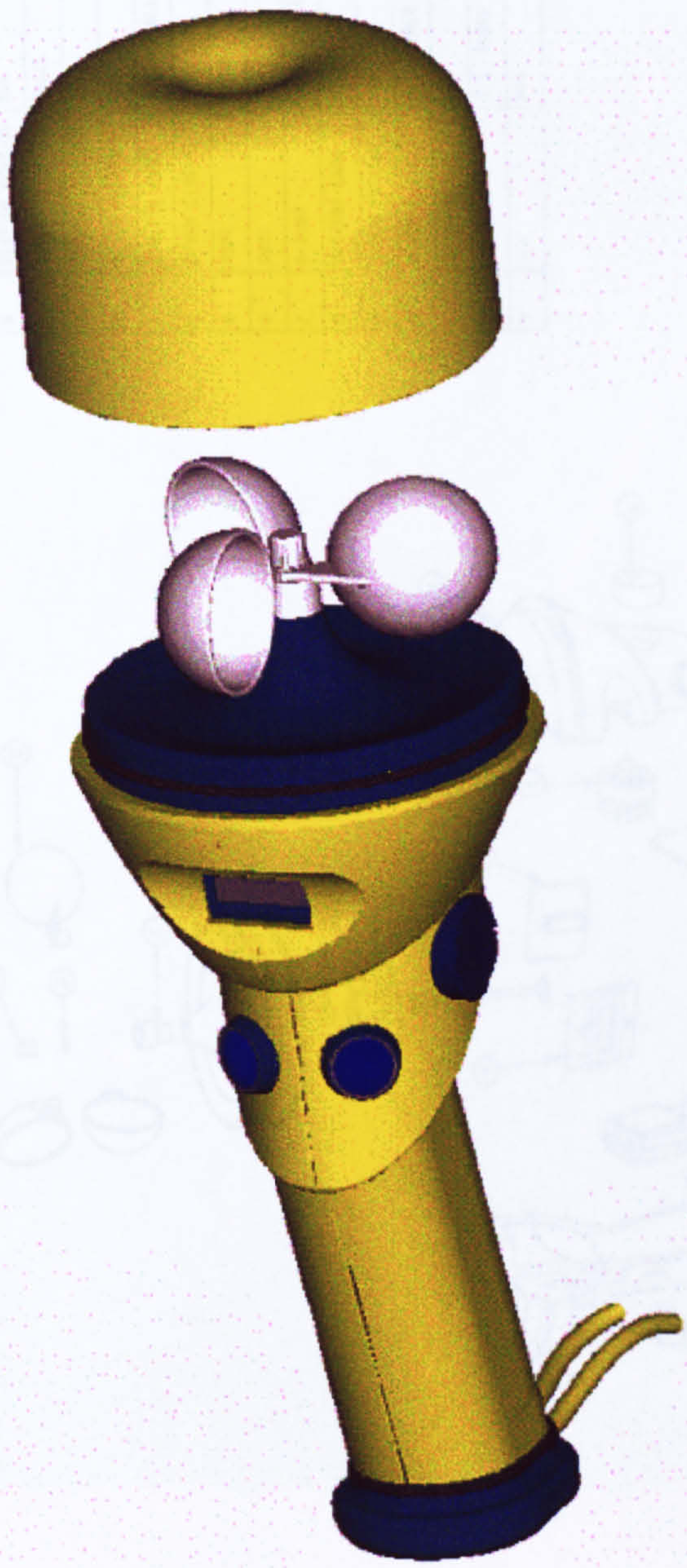


Plate 2.6 Hand held Wind Anemometer,
Level 2 BSc CAPD Design Practice module. Design and make group project.
Modelled in ProEngineer by R P Laney and D M Hesmondhalgh

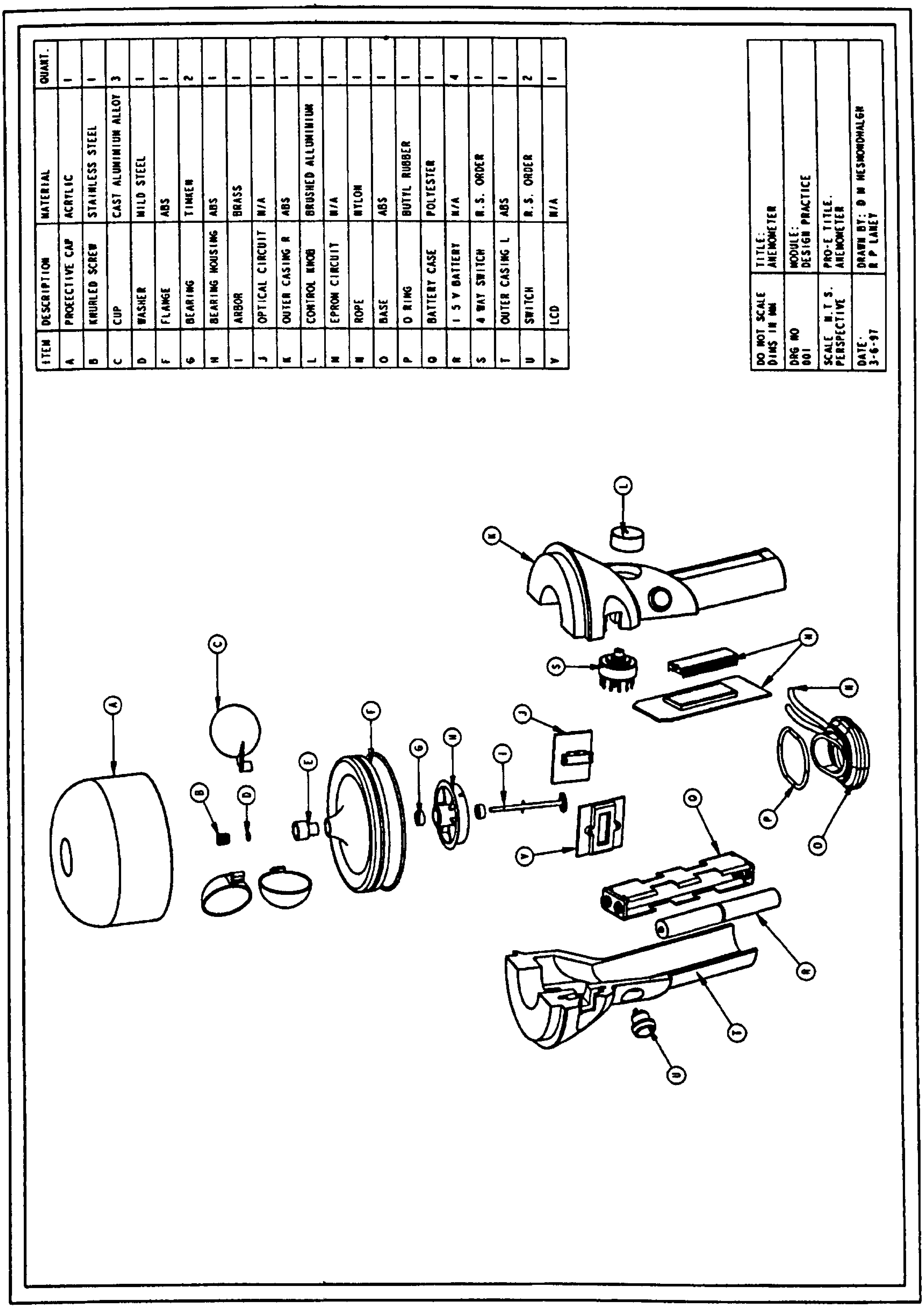


Plate 2.7 Hand held Wind Anemometer, Exploded View.
Level 2 BSc CAPD Design Practice module. Design and make group project.
Modelled in ProEngineer by R P Laney and D M Hesmondhalgh

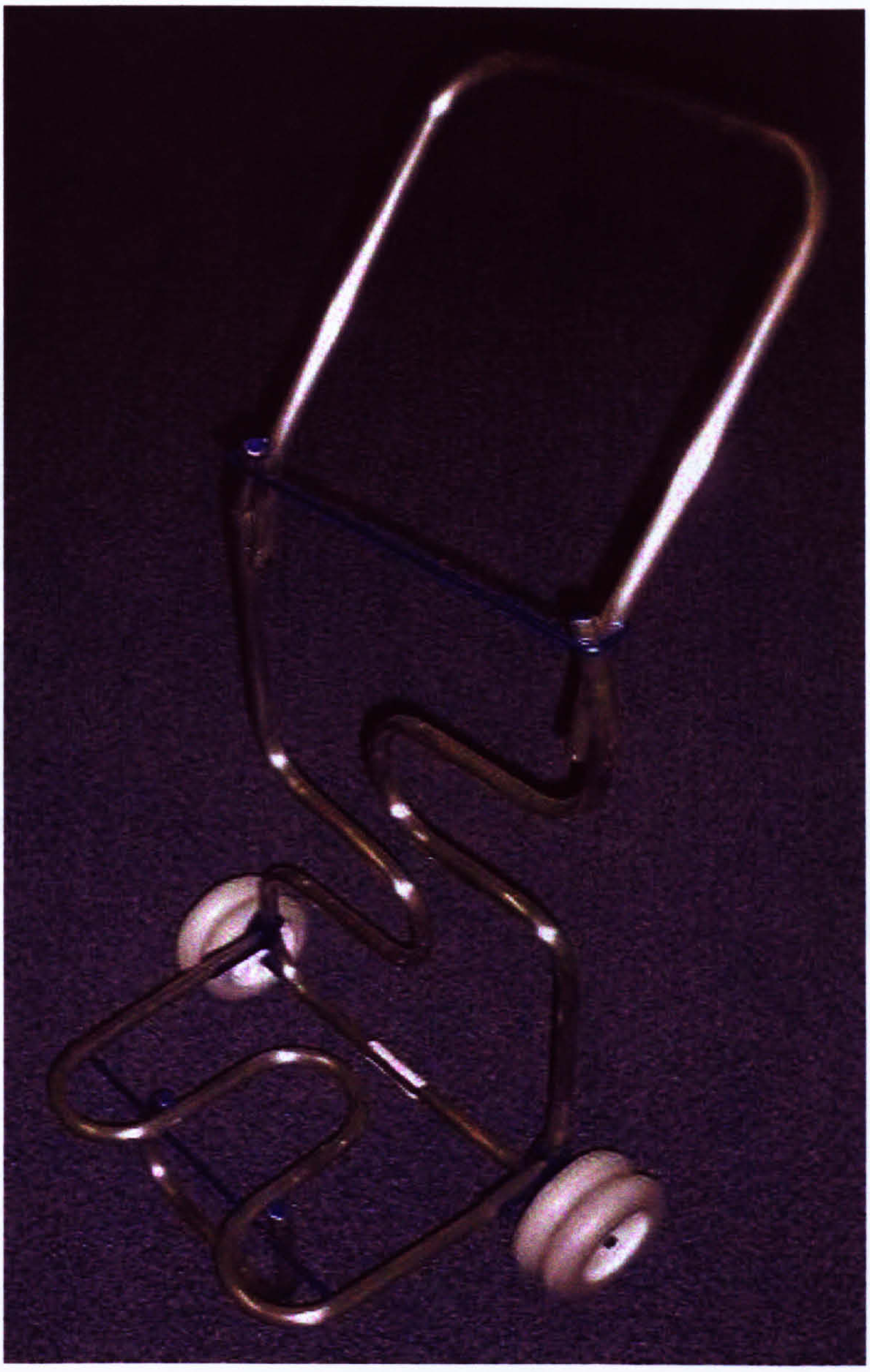


Plate 2.8 Collapsible Water Carrier for the caravan market. Product makes use of bent tube with no welding for reduced manufacturing/production costs.
1997/1998 Level 2 BSc CAPD Design Practice module.
Designed and produced by Martin Wilcockson and Martin McBrearty

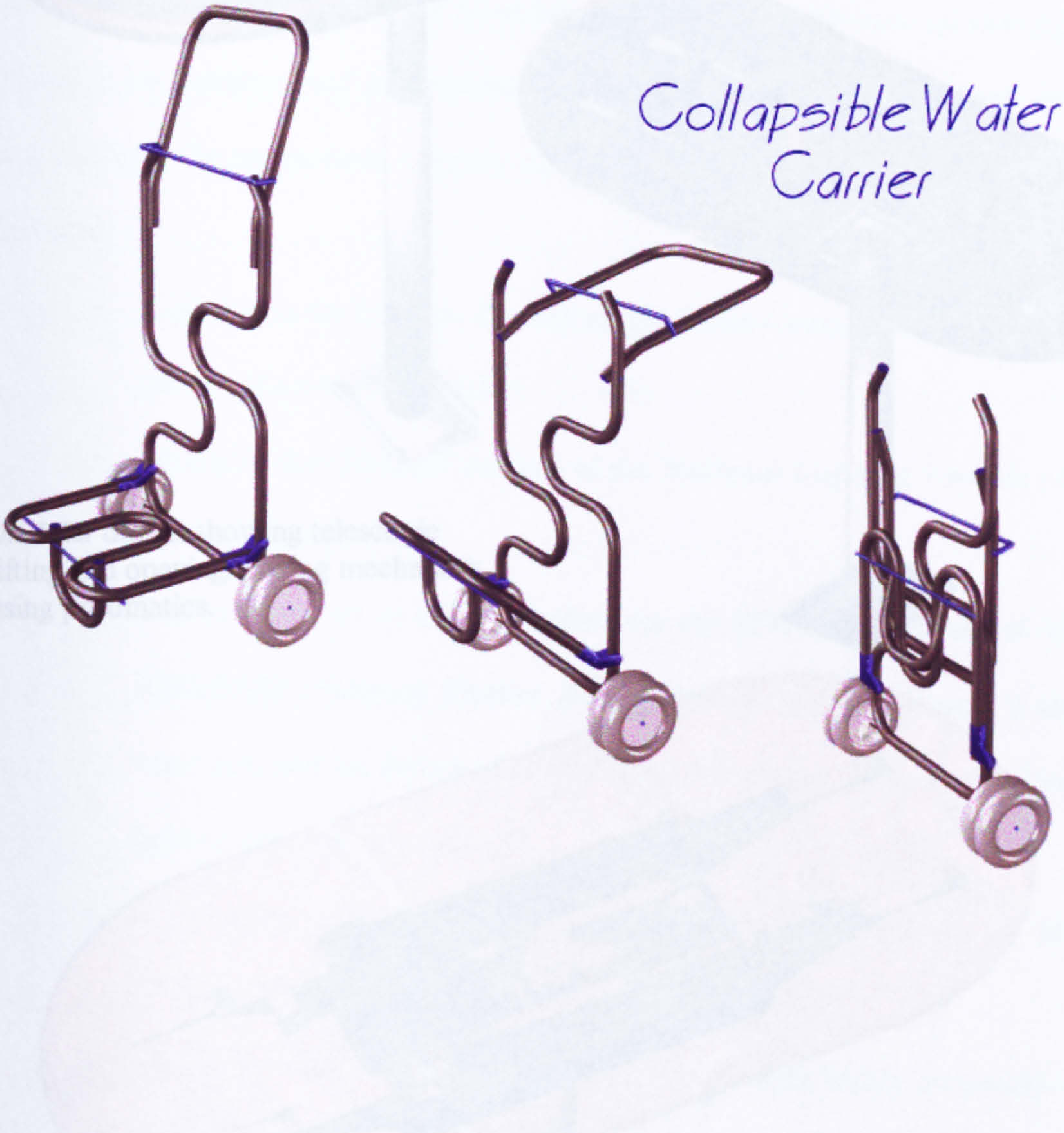
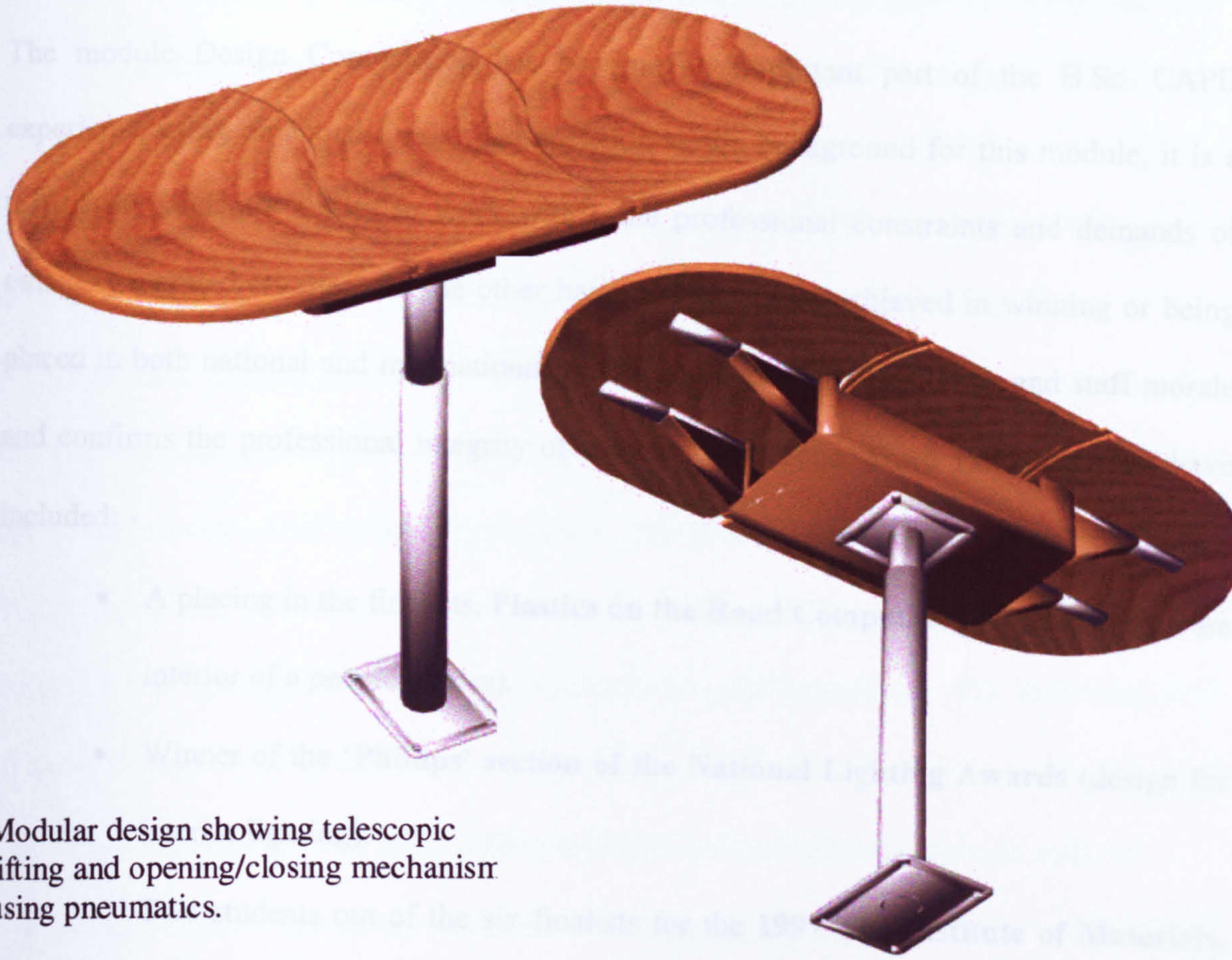


Plate 2.9 Collapsible Water Carrier for the caravan market, showing method of folding.
1997/1998 Level 2 BSc CAPD Design Practice module.
Designed and produced by Martin Wilcockson and Martin McBrearty



Modular design showing telescopic lifting and opening/closing mechanism using pneumatics.

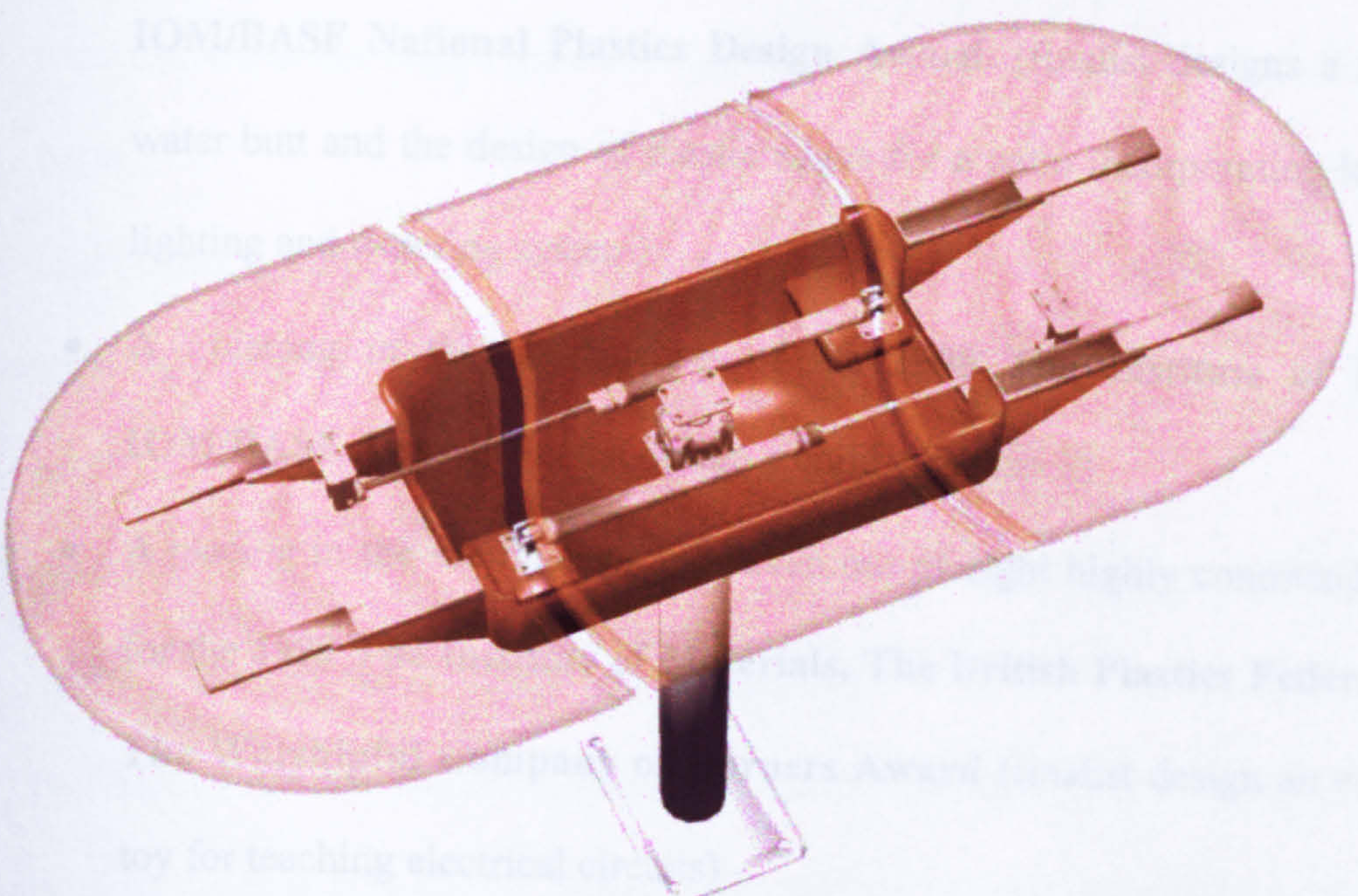


Plate 2.10 Winning modular design of a dining table that transforms into a coffee table for a luxury yacht. 1999 industrial sponsored group project. Level 2 BSc CAPD Design Practice. Produced by G. Southall, C. Taylor and C. Turton.

2.3.4.4 Level 3, Year 3 Design Competition

The module Design Competition has become an important part of the B.Sc. CAPD experience using an actual Design Competition as the background for this module, it is a test of the student's ability to work within the professional constraints and demands of outside generated criteria. On the other hand, the successes achieved in winning or being placed in both national and international events is a boost to both student and staff morale and confirms the professional integrity of what is being done. Since 1996 successes have included: -

- A placing in the finalists, **Plastics on the Road Competition** (finalist design the interior of a people carrier).
- Winner of the **'Phillips' section of the National Lighting Awards** (design for interior lighting).
- Two students out of the six finalists for the **1997 The Institute of Materials, IOM/BASF National Plastics Design Award.** (finalist designs a collapsible water butt and the design of plastic edges for a patio incorporating low voltage lighting and watering system)
- A placing in the six finalists of the **1998 The Institute of Materials, IOM/BASF Award** (finalist design a child's rucksack)
- A placing in the six finalists and seven out of eight highly commended entries for the **1999 The Institute of Materials, The British Plastics Federation and The Worshipful Company of Horners Award** (finalist design an educational toy for teaching electrical circuits)

- A placing in the six finalists for the **2000 The Institute of Materials, The British Plastics Federation and The Worshipful Company of Horners Award** (design of plastics in city life)

The 1998 design competition project is used as an example. This required the design of a piece of luggage using polymers as the main construction material of the product.

The project had a tight calendar with two main target dates for the submission of work; the first was early December 1997 when the majority of the design work had to be presented and which accounted for 75% of the marks. The second and final hand-in included the project report that accounted for the other 25% of the grading. As this was a final year project, it was intended to be a test of the students' professionalism. The four main skill areas were expected to be manifest in this project: -

- Visual communication skills in the presentation drawings and proposed solution.
- Design in the development work and three-dimensional models.
- Manufacture in the design specification, which also gives an estimation of production costs.
- Computing CAD drawings and 3D modelling

Students were given suggested areas for the product design: -

- a hand-held or hand propelled carrying device
- weekend bags
- sports bags (with the exclusion of golf trolleys)
- rucksacks (with the exclusion of shopping items, e.g. shopping trolleys)

A number of the best BSc CAPD Design Competition projects are selected by the design team for entry to the competition. A panel of members from 'The Institution of Materials' then judges the projects on a national level and selects the six finalists from all the Universities and college entrants. All finalists then have the opportunity to exhibit their work at 'The Institution of Materials' headquarters and meet key personnel involved in the Plastics industry. The BSc CAPD students who have been finalists in the past gain a lot of prestige from this and often gain work placements and job opportunities.

The following four plates show two of these designs. The first plate a 'collapsible water butt'; unique in that it can be transported in a collapsed state i.e. reduced volume, ideal for use in disaster hit countries following hurricanes, tornado's etc (BSc CAPD Design Competition finalist 1997. The Institute of Materials, IOM/BASF National Plastics Design Award). The other three plates show three presentation boards of the Cirkit toy. (BSc CAPD, 1999 Institute of Materials National Design Competition finalist)

Plate 2.11 Collapsible Water Well. Designed and produced by Nabil Salah.
1997 BASF National Design competition finalist.

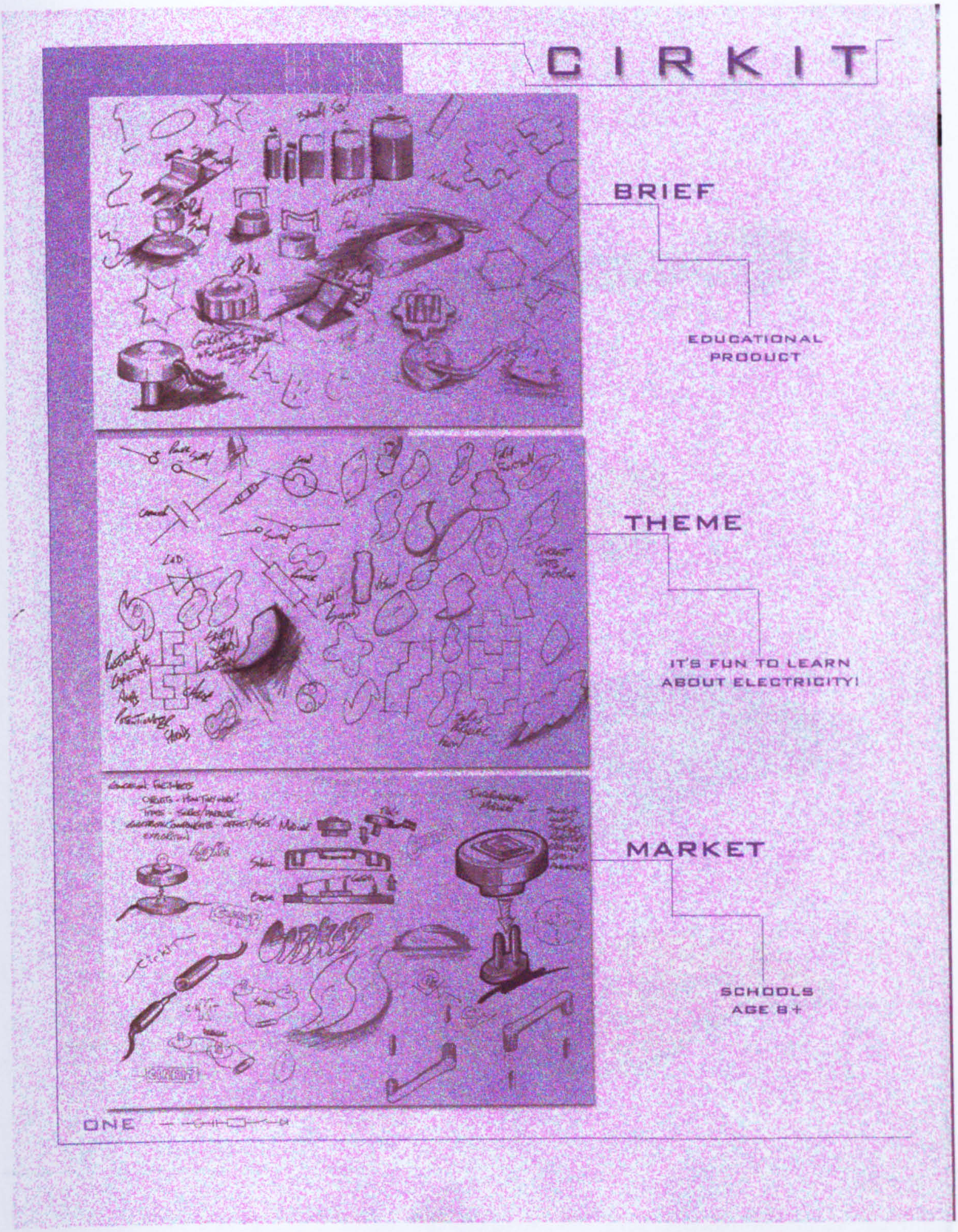


Plate 2.12 Concepts Board for Cirkit toy. Designed and produced by Martin McBrearty, BSc CAPD.1999 Institute of Materials National Design Competition finalist.

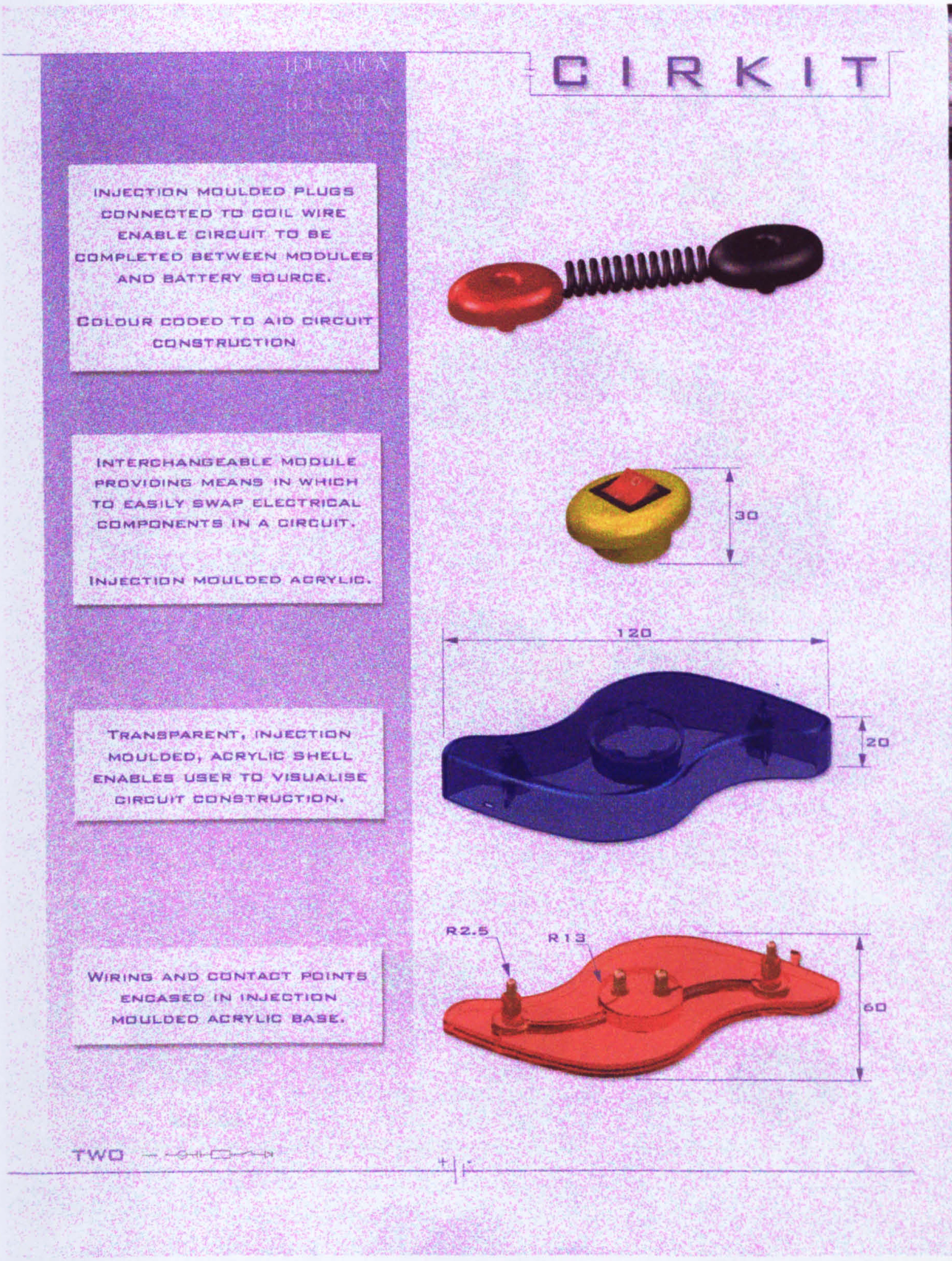


Plate 2.13 Components Board for Cirkit toy. Designed and produced by Martin McBrearty, BSc CAPD.1999 Institute of Materials National Design Competition finalist.

Plate 2.14 Components Assembly Board for Cirkit toy. Designed and produced by Martin McBrearty, BSc CAPD. 1999 Institute of Materials National Design Competition finalist.

2.3.4.5 Level 3, Year 3 Projects

Half of the final year, that is one semester, is devoted to project modules. These include Project Planning, Design Enterprise Project and a self-initiated major Design and make project. Project planning represents the initiation phase of the final year design and make project. It allows the student to select and research their chosen topic, identify a marketable product innovation, draw up a management plan for design and produce a detailed design brief based on market need for a suitable product design.

The major project is expected to be developed to first working prototype stage and involves considerable time being spent in workshops. There are no formal lectures for this module, but students meet with the project supervisor at intervals to report on progress and/or problems with the project. A display is required by the end of the semester that is restricted to a 2.5 m x 1.5 m board. This contains an explanation of the project idea with suitable 2D and 3D computer aided design modelling plots to demonstrate expertise in these techniques, plus a Finite Analysis (FE) of some aspect of the project structure, again to demonstrate expertise in this method. The prototype is presented at the same time as the displayed boards. A written report is also produced by the student containing the project rationale, the preliminary background research, the proposal and its innovative feature/s, problems in achieving the required solution, the appropriate modelling plots, FE analysis and finally conclusions.

Final project topics have been wide ranging and include products allied to every market e.g. in the automotive sector such as child seats in cars, thief protection devices, safety aspects including roll bars for coaches and airbag design for Formula 1 racing. Products allied to the leisure market have been exercise benches, suspension for bicycles, Jet Ski, and boot fastening for snowboarding. Electronic projects include an automated golf ball loader for driving ranges, progressive brake light indicators, mobile phone, satellite navigation for yachts, fire warning device for deaf people and other projects for the disabled including walking aids, bath lowering devices and specialized chair design.

The Design Enterprise project is a simulation of today's competitive market. Students are divided into small groups and asked to set up a small new company to design, manufacture and market a given product. The Design Enterprise Project is designed to develop in students the ability to work in a team as part of a design innovation and implementation project, and to integrate many of the discrete subject areas that have previously been studied. On completion of the module a student should be able to:

(1) Appreciate the integration of the resources of materials, equipment, finance and skills involved in a manufacturing enterprise.

(2) Appreciate the inter-relationship between the market needs, design and production and in particular of operating within the limits of financial constraints.

(3) Understand the skills required transforming an idea into a functional, economically viable and aesthetically satisfying artifact.

(4) Manage people and personal effort, in communicating with others and working in groups,

(5) Accept responsibility for decisions and to recognise when and how to seek help.

A fortnightly team meeting, at which minutes are taken, is held (with a staff member in attendance) to monitor progress. A member of staff is available to suggest avenues of approach and to indicate sources of information but essentially it is for the students to run the project by seeking out new information and integrating knowledge from their previous studies. This involves the following tasks:

- Design a product and generate a design specification e.g. a scaffold tower, electric toaster etc.
- Decide on the appropriate manufacturing methods and determine the equipment required including its cost.
- Assess the national market for the given product and suggest a marketing strategy for the initial period of the company's life.
- Investigate sources of finance and prepare a business plan for the first five years of the proposed company.

On completion of the module a visual presentation, either by video or CD-ROM, is made to other students, staff and interested companies of the design and the business plan. A written report is also required, containing the requisite information regarding the design proposal, the manufacturing requirements, business plan and marketing proposals.

2.3.4.6 Student Perceptions

Students entering the course come from a wide range of backgrounds and experiences. When talking to students the one thing that they have in common is an interest in practical design. At the end of the day, most want hands-on experience being involved in both designing and making. It is the project base which is the attraction factor of the course and which, along with computing, is the areas that students enjoy and in which they achieve most success, a success they take into their careers. The following plates show a diverse range of past BSc CAPD, Level 3 Projects.

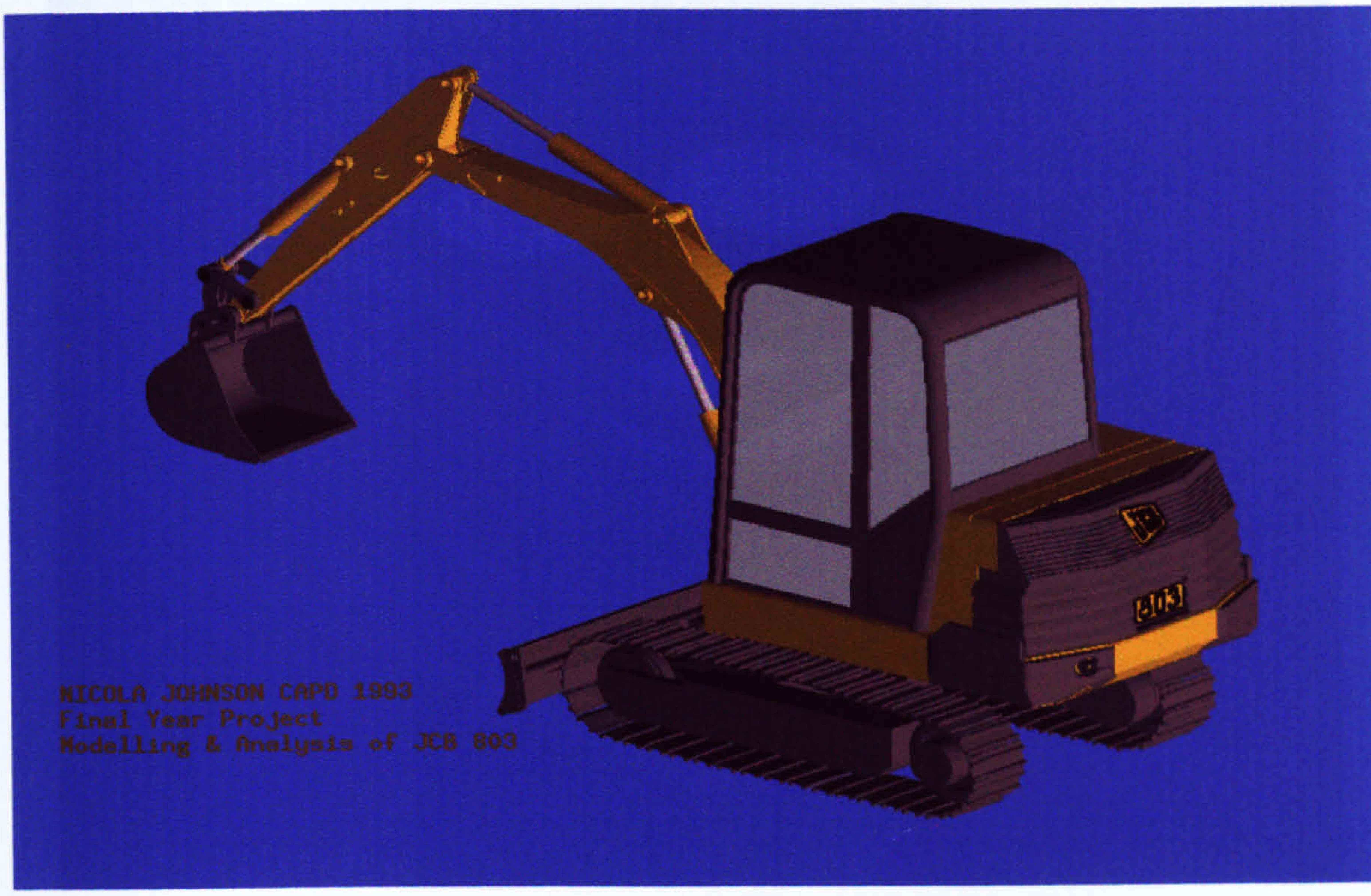


Plate 2.15 JCB 803 Excavator.
BSc CAPD Final Year project modelled in Aries Solid Modeller

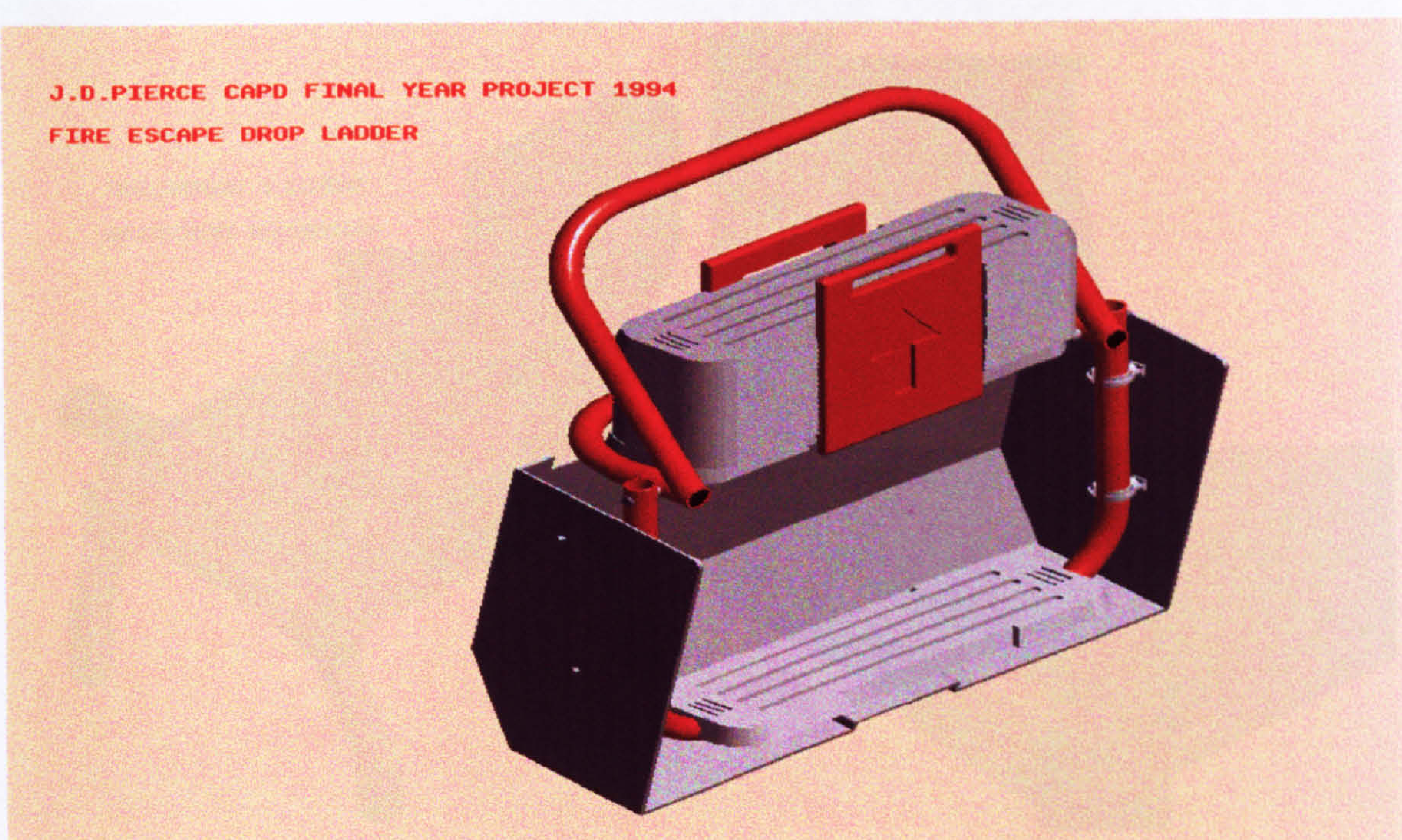


Plate 2.16 Fire Escape Drop Ladder.
BSc CAPD Final Year project modelled in Aries Solid Modeller

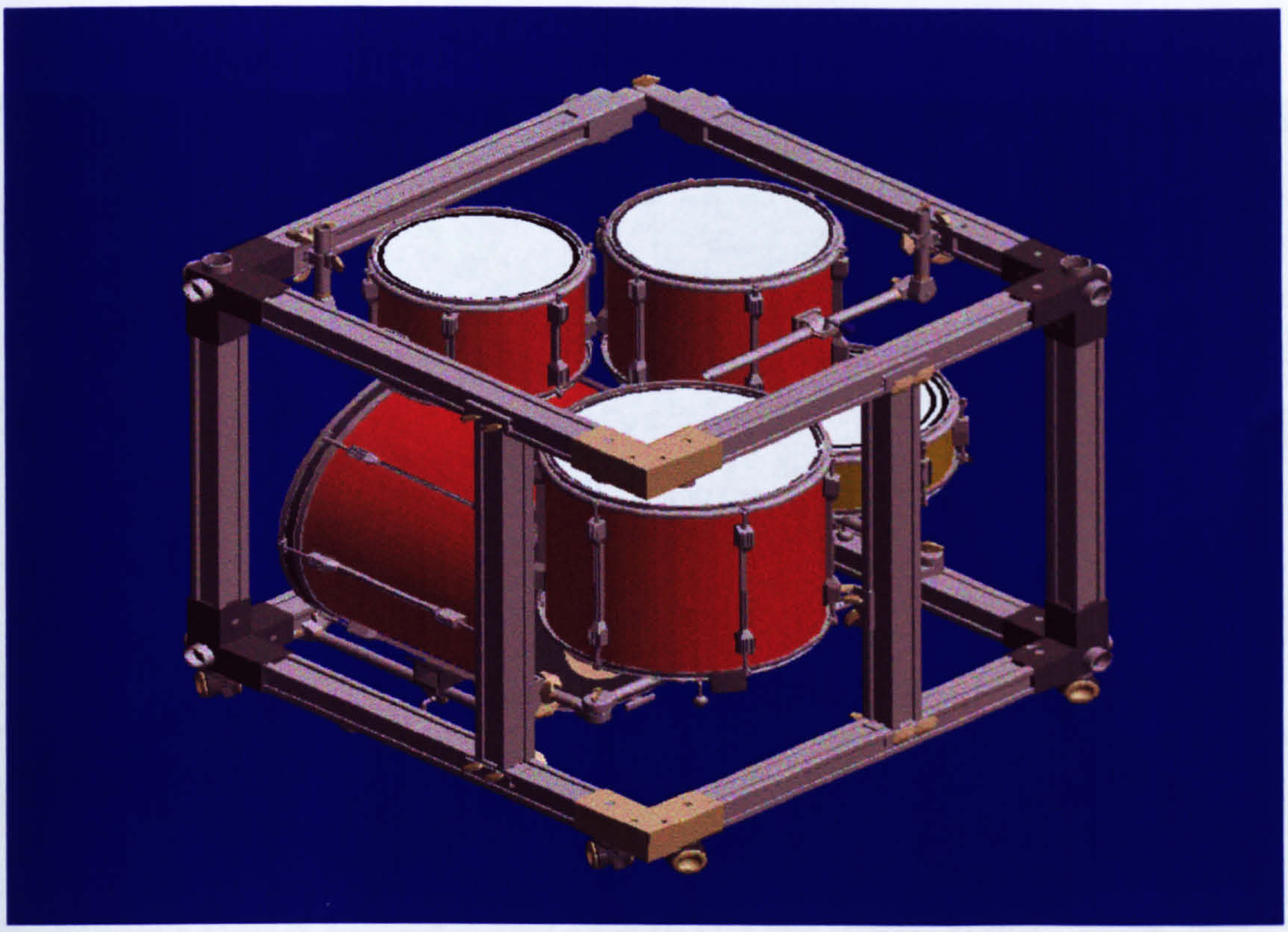


Plate 2.17 Modular Protective Cell for transporting Drum Kit.1994 BSc Final year project designed by Stephen Brooks.

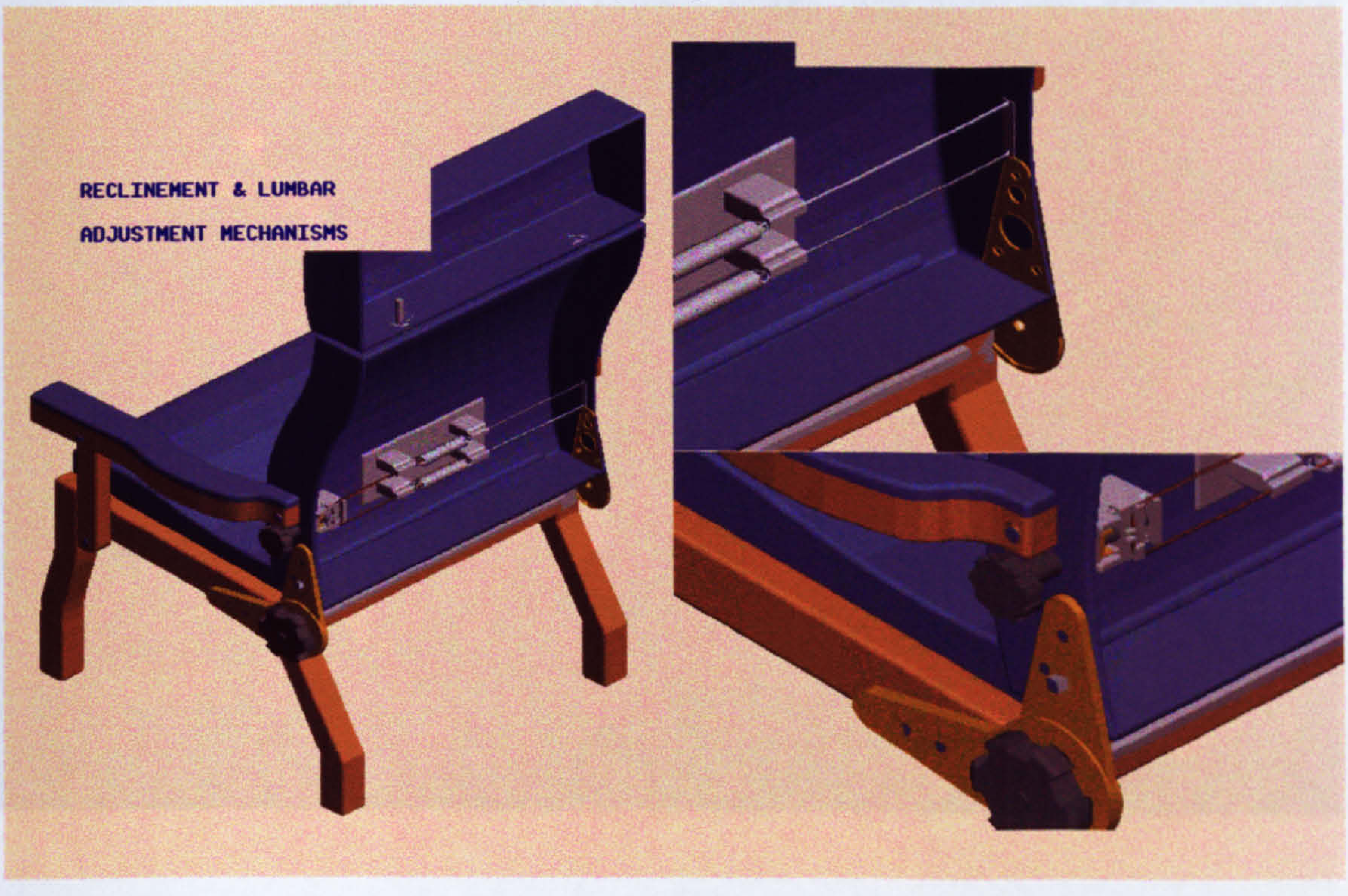


Plate 2.18 Orthopaedic Reclining Chair showing Lumber Adjustment Mechanism. BSc CAPD 1994 Final year project modelled in Aries Solid Modeller by A. Gill

Plate 2.19 Gas Powered Weed Burner showing assembly and burner unit.
Modelled in Aries by D. Wild.

Computer Aided Product Design. 1999/2000 Final year project examples.

Plate 2.20 In-line skate brake with hand held brake actuator produced by Vincent Au

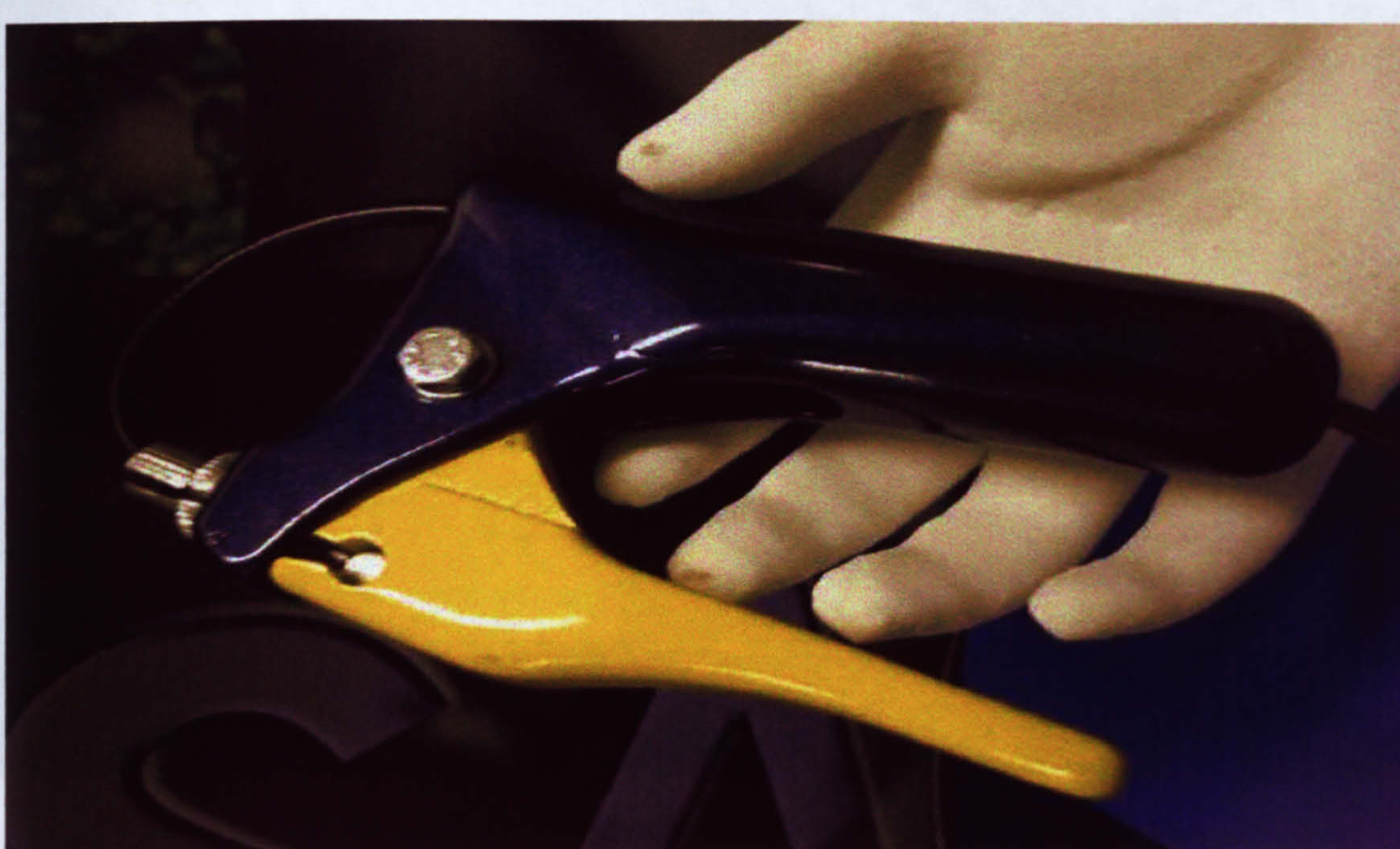


Plate 2.21 Sliding electrical sockets designed by Darren Dixon

Plate 2.22 Jet Ski trailer designed by Simon Wright

Plate 2.23 Sliding pick-up for guitar designed and produced by Edward Bruce

Plate 2.24 Sash-window electric opening/closing actuator designed by Matthew Rogerson

Plate 2.25 Barrel Lifting Trolley for manoeuvring Beer Barrels in Public House cellars. Designed by Gary P Smith

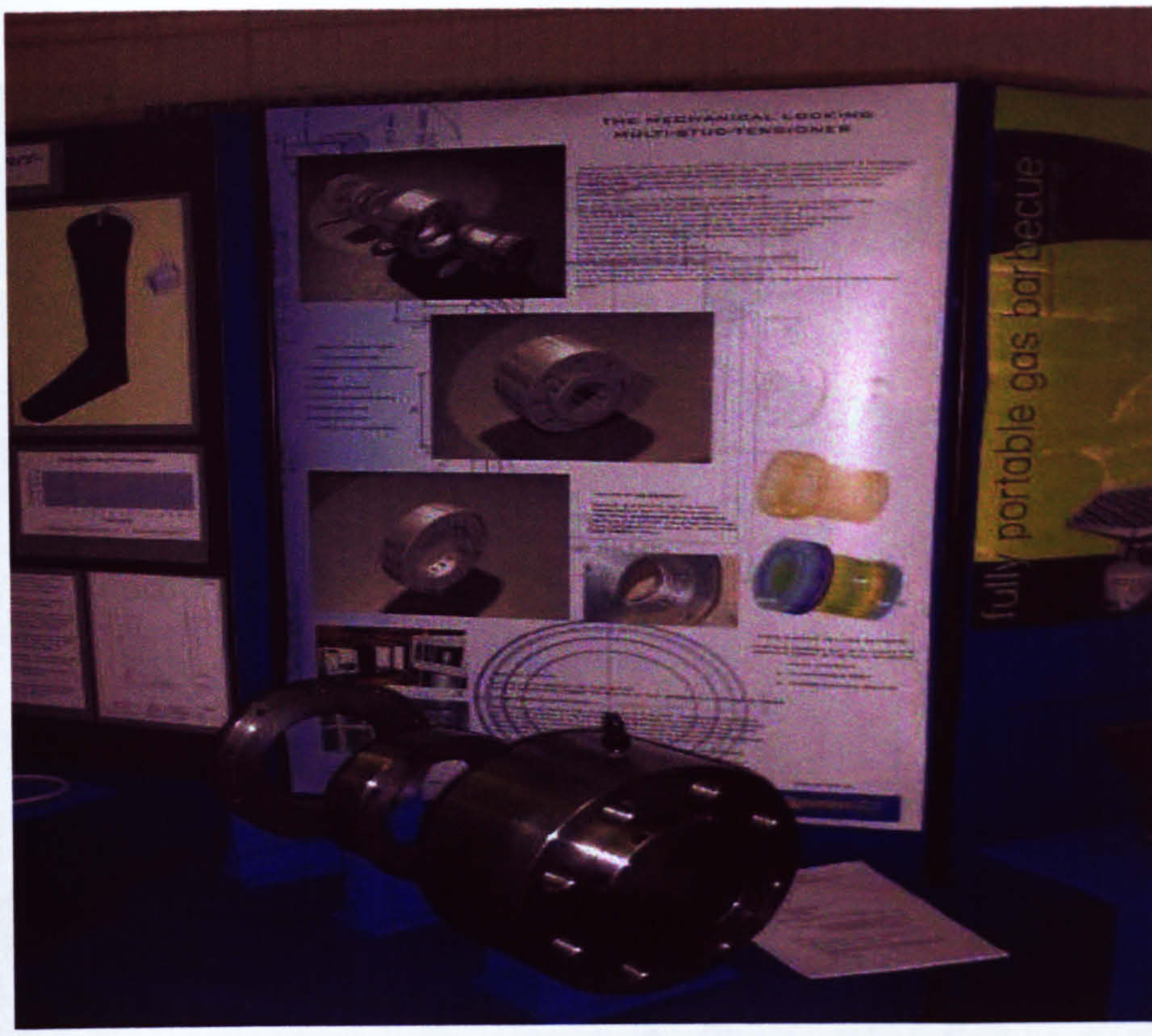


Plate 2.26 Semi-remote under-sea oil pipeline connector by Lee Dalton

Plate 2.27 Rotating frame for Jet Ski maintenance designed by Simon Gardner

Plate 2.28 Inflatable shelter for the homeless designed by Darren Walker

Plate 2.29 Re-usable postage boxes designed by Stephen Gibson using ProEngineer solid modeller. Boxes Rapid Prototyped using Stereolithography techniques.

2.3.5 The Industrial Experience Year

The course was originally validated as a 'sandwich only' award and this caused considerable problems in the earlier years of the course because of the extreme difficulty in finding suitable sandwich placements. Each year special permission had to be sought for a full time award to be made to the majority of each cohort. In 1992, validation was sought and granted for a full-time award to be added to the sandwich mode. Therefore this is now an optional year which occurs between level 2 (Year 2) and Level 3 (Year 3) is very much dependent upon the students. It is based around their initial aims and ambitions and their personal tenacity to find a place, obviously they are given considerable staff support in doing this and an Industrial Placements officer co-ordinates it.

The requirement for the sandwich award is to undertake a minimum of 36 weeks 'design related experience'. This was deliberately phrased in this way at the inception of the award to give the possibility of a wide variety of training opportunities. Indeed there has been a wide variety of training placements obtained, reference Appendix II 'BSc CAPD STUDENT PLACEMENTS' shows a listing of companies who have provided placements during the period 1995/96 to 1999/2000, on a few occasions a company has taken on two of our students at a time. The placements range from a conventional engineering design type placement at Jaguar Cars through a placement introducing CAD into a small manufacturer to a design consultancy producing animation software. The experience gained has, in the majority of cases, shown itself in the maturity of work carried out in the final year.

The placement student is given a comprehensive set of guidelines, reference: - [28]'Student Handbook For The Year Out Placement'(1998) identifying timetable of events, maintaining

[28] *Student Handbook For The Year Out Placement* (1998) Author: - Hudson, G. University of Wolverhampton, School of Engineering and the Built Environment, Engineering Division, England.

a logbook, industrial training assessment, and the industrial supervisor's/academic report etc. Ideally, the student is visited twice by the Academic supervisor during the placement period, this is however, dependent upon the location of the placement. On these occasions the tutor meets both the Industrial Supervisor and student to discuss the student's progress and inspect his/her logbook. Final assessment is provided through a written report by the student and two assessment forms, one of which is completed by the Industrial Supervisor and one by the Academic Supervisor a copy of the form is included in Appendix II for reference. The assessment for the Industrial Placement is either a Pass or Fail.

Table 2.2 shows the numbers for students who have secured a year out placement between 1995 and 1999. The figures are based upon enrolment figures for that year and take into account the number of students that withdrew. It can be seen that the number of students obtaining placements, as a percentage increased steadily from 29% in 1995 to 41% in 1998. This represents approximately 20 students on placement for each year. However, 1999 figures show a remarkable fall in the number of students gaining placements, just five students, representing 12% of the students. A number of factors may be attributed to this. Student grants have been replaced by student loans and student University fees were introduced in 1998 making it more expensive for students to study over a four year sandwich degree compared to a three year full time mode of study, especially if they are living away from home. This is apparent when interviewing existing students. It may be that this is just a one-off year, or more worrying companies are not recruiting placement students for training as they have done in the past, for whatever reason. This will need monitoring in the future. Placements and work experience are further discussed in the thesis, chapter 4.73 '*Work Experience, Q8 Is previous work experience essential*', 4.77

Year	1995/96	1996/97	1997/98	1998/99	1999/2000
Number of 2nd year students enrolled taking into account withdrawals	69	55	59	44	39
Number of students who obtained a placement	20	19	22	18	5
Number of students who obtained a placement as an approximate percentage of the total number	29%	34%	37%	41%	12%

Table 2.2 Number Of BSc CAPD Students Gaining Year Out Placement (1995 - 1999)

'*Business, Q29 Foreign Language Requirement'* (students working abroad), 4.9.2 *'Work Experience'* and 4.9.8.1 *'Practical Experience, Manufacturing'*.

Students who have gone out on placement have found the experience beneficial for a number of reasons.

i) They learn the importance of working as part of a team and company procedures.

ii) They develop a professional maturity from their experience.

iii) Many have gained a placement abroad and during the year become reasonably fluent in a European language.

iv)Many students carry out a company-based project in their final year.

v) There is often the offer of a permanent position within the company when they finish their degree.

However, it has been observed that a number of students, on returning to University from their placement to complete their final year, experience difficulty in adjusting back to full-time education, in particular working at evenings and weekends etc. In industry they have adjusted to set hours of 9.00 to 5.00 with evenings / weekends free. This has led to staff making placement students aware of this on their return during the induction week and offering study support. The Award Leader now routinely warns the returning students of this danger and the need to work consistently from the start of the final year.

2.3.6 Admission And Progression Of Students

It can be seen from Table 2.3 that the 'drop out' rate is greatest in the first year. Despite our best efforts before recruitment to explain the nature of the course, there are a number of

	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
Year 1								
Enrolled	40	43	82	66	72	52	41	42
Withdrawn/transferred	2	1	8	2	8	11	3	8
Year 2								
Enrolled	24	39	53	75	57	61	45	40
Withdrawn	1	1	1	6	2	2	1	1
Year 3/4								
Enrolled	16	22	36	48	58	59	55	45
Withdrawn/deferred	0	4	1	6	6	1	2	2
Failed	0	0	0	1	0	0	0	0
Completed BSc CAPD	16	18	35	43	52	58	53	43

Table 2.3 BSc CAPD Student Admission and Progression

students each year who find in the first semester that it is not the type of award for them. These students then either transfer to another course or leave the University.

The overall failure rate for each year is generally quite reasonable, but this overall rate disguises a high failure rate in certain modules, these being the more technical modules. This situation has been a source of concern to the award team for some time and various teaching and learning changes have been made to try and improve this aspect of the students' performance. This culminated in an alteration in the teaching of some mathematics in the first year and a change in some of the Fundamentals of Technology syllabus content. Mathematics is now taught by engineering design staff and the use of computer software has also been introduced to assist in making the topic more stimulating.

Table 2.4 shows the number of BSc CAPD students who have completed the award between 1991 and 1999 and their degree classification. When comparing the totals for each year, i.e. the number of final year students enrolled to the completed number, it is encouraging seeing that virtually all of the students graduate. Very few students fail and withdraw at this stage. Of the first cohort of sixteen finalists, the Honours Degree classification was equally split between eight Second Class upper division and eight Second Class lower division. As the number of final year students has increased over the years to a maximum of 59 in 1996/97 so the number of First Class Honours degree classification has increased to its highest figure of seven during that year. Likewise the majority of the other students fall into either Second Class Honours Degree upper division or Second Class Honours Degree lower division.

Finalist Classifications	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
First Class	0	1	1	3	5	7	6	5
Second Class -upper div'n	8	6	20	21	20	24	27	30
Second Class -lower div'n	8	9	13	18	25	23	18	7
Third Class	0	0	1	0	0	1	1	0
Unclassified	0	1	0	0	1	1	0	0
Dip HE	0	1	0	1	0	2	0	1
Cert HE	0	0	0	0	1	0	1	0
Deferred	0	4	0	2	6	1	2	2
Totals	16	22	35	45	58	59	55	45
Completed BSc CAPD	16	18	35	43	52	58	53	43

Table 2.4 BSc CAPD Student Completion of the Award 1991-1999

2.4 Comparison Of Product Design Courses

Comparing the Industrial Design programme at TU Delft and the BSc CAPD course at the University of Wolverhampton, the main difference is the scale of enrolment. Delft enrolled approximately 200 students onto their 1st Year in 1985, making it one of the largest input of students throughout the world for a prescribed course. This number rose to approximately 300 students in the 1990's, compared with the University of Wolverhampton's largest number of 82 on the BSc CAPD. This large number of student enrolment at Delft is attributed to two factors. In the first instance, Delft University is renowned throughout Holland for its Industrial Design programme and, secondly, the educational system in the Netherlands allows entry to a University by right, which is granted to all applicants, legally no entrance selection can be used. In general if a student has the appropriate entry qualifications the Dutch institution by law is required to offer them a place.

Although in TU Delft lecture group sizes are large, students are allocated to groups of approximately 20 for tutorial sessions. The institution employs technical writers and at the commencement of each module each student receives a comprehensive set of lecture materials. There is no requirement for students to attend lectures and consequently attendance figures tail off as the semester progresses.

In Holland there are relatively few institutions offering similar courses in Industrial / Product design at degree level, unlike in the UK where there has been a significant growth in the number of design courses being offered, as previously discussed. Reference Appendix 1, (List of Product Design Courses in England, Northern Ireland, Scotland and Wales). 1993/94 showed no less than 42 competing colleges and Universities offering a form of higher education in Industrial / Product Design. The average intake for first year students was approximately 25 per UK institution, there were just a few exceptions to this whose targets were 90-100 students.

By 1999 UCAS data showed the number of UK institutions offering product design programmes had risen to 58, an increase of 75.75 % over six years, with many variations and options made available on the product design theme.

The industrial design course at TU Delft is very intensive with considerable emphasis on mathematics and physics and tends to have a fairly high failure rate (approximately 40%) of students across each year. Typically only 15% of the original students entering the Industrial design programme at TU Delft graduate with the Degree "Master Industrial Design Engineer" (M.IDE) within the allocated time.

The failure rate or transfer of students from the BSc CAPD course is much lower approximately 10% in the first year, 10% second year and 5% in the final year.

The design of many Dutch Universities dictates there is very little on site student accommodation, for what accommodation there is there are long waiting lists, unlike many UK Universities where significant expansion has taken place. Many Dutch exchange students staying in halls at the University of Wolverhampton have valued the effectiveness of on-site accommodation and being able to study in such close proximity to the institution. Students studying at TU Delft often travel many miles via public transport to their campus.

Students in Holland have to pay college fees but benefit from a five-year government grant for basic living expenses paid to them on a monthly basis. This grant is less for students living at home than for students living away from home. In addition to students loans being made available, they also receive a free public transport card which is either valid during the week for travelling to University or weekends for travelling home, depending upon where Dutch students reside during their studies. It would appear that

UK students are far worse off financially than their Dutch counterparts with fewer grants for living expenses, the introduction of course fees on a yearly basis and no free travel unless provided by the University.

The academic year is much longer in TU Delft, 4 terms of ten weeks i.e. 40 weeks compared with our 2 semesters of 16 weeks = 32 weeks. Both these figures include exam weeks.

As previously pointed out the TU Delft Faculty of Industrial Design Engineering programme offers a full five-year curriculum leading to a masters degree. In the fourth and fifth year a number of elective courses can be followed which gives the student the opportunity to follow a programme tailored to his or her individual vocational needs.

In the UK students can obtain a masters degree in four years full time mode of study. However, if the student undertakes a four-sandwich degree, including the placement year followed by one-year full time MSc, then they can accrue a significant amount of industrial experience comparable with that of their colleagues studying at TU Delft.

Two main objectives remain the same when comparing the Industrial Design programme at TU Delft and the BSc CAPD course at the University of Wolverhampton. The first is the integration of design projects into the curriculum and the second is the integration of computers into design.

Chapter 3

3.0 Innovative Approaches To Teaching And Learning

[1]Heskett (1987 pp. 159-160) discusses how efforts were made in the late 1960s to explore the possibilities of new technology applied to education. Up to this point, mass-production and improved design had influenced the physical context of education, such as modular classroom furniture that could be arranged to suit different teaching styles. The introduction of the overhead projector in the 1950's, allowing text and diagrams to be projected onto a screen, made an impact in replacing much of the traditional chalk and blackboards. Automatic slide-projectors introduced in 1961, such as the Kodak Carousel designed by Hans Gugelot, stimulated the projection of visual materials. However, one of the most technological transformations was the introduction of Language Laboratories. Students could respond individually and simultaneously to the teaching programme, whilst sitting at their individual console, equipped with controls and headphones linked via a central tape-recorder.

During this period Philips, the Dutch company, produced a speculative design for a Learning Unit called the "Teacher-aiding Electronic Learning Link" (TELL) designed under Knut Yran and presented in 1970. At the time it was very futuristic having, as Heskett describes, "an air of science-fiction fantasy when compared to the reality of most classrooms. A large integrated console in white moulded plastic was equipped with video and audio equipment, giving access to a wide range of information sources". The major obstacle at the time was the cost; however, Philips had demonstrated a radical possibility in the way in which we learn.

This chapter deals with how developments in technology, especially the computer and computer software, have been used in supporting new initiatives in product design

[1] HESKETT, John. (1987) INDUSTRIAL DESIGN. London :Thames and Hudson Ltd, pp.159-160.

education at the University of Wolverhampton in the School of Engineering and the Built Environment. Some of this research has previously been published and presented as refereed conference papers by the author and is referenced as below.

The use of Parametric CAD as a teaching aid in the early stages of the BSc CAPD course is discussed, reference [2]Felton (September 1994 pp.313-322) and [3]Felton (10th-11th July1995). Parametric CAD (dimension driven CAD software) at the time 1994/95 was still relatively new compared with today's sophisticated 3 Dimensional (3D) Parametric CAD tools.

The evaluation of Video Conferencing in a distance learning environment, at the time in its infancy is also discussed, reference [4]Felton (3rd-5th July 1995 pp.225-233), [5]Felton (6th September 1996) and [6]Felton (28th-30th October 1996 pp.87-95). This is followed by the further development of a computer-aided learning (CAL) package for teaching 2 Dimensional (2D) CAD skills and its evaluation.

3.1 Four Levels Of Computer Use In Product Design

Europe's Education Magazine [7]'Syllabus' (Autumn 1993, pp.8-10) published an article 'Four ways in which computers can enhance higher education instruction' which is

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[2] FELTON, A. J. *Evaluation of CAL in undergraduate courses,* Computer Aided Learning in Engineering Conference, University of Sheffield 5th-7th Sept 1994, pp. 313-322.
[3] FELTON, A. J. *The Evaluation of Parametric CAD as a Teaching Aid in Product Design,* 2nd National Conference on Product Design Education, Coventry University 10th-11th July 1995.
[4] FELTON, A. J. *The Evaluation of Video Conferencing in a Distance Learning Environment,* International Conference Hypermedia in Sheffield 95, University of Sheffield 3rd-5th July 1995, pp. 225-233.
[5] FELTON, A. J. *The Evaluation of Video Conferencing in a Distance Learning Environment for Product Design,* Thirteenth Conference of the Irish Manufacturing Committee, (Re-Engineering for World Class Manufacturing), University of Limerick 4th-6th September 1996.
[6] FELTON, A. J. *The Evaluation of Desktop Video Conferencing in a Distance Learning Environment for Product Design,* Wolverhampton University, School of Education Annual Research Symposium, 28th-30th October 1996, pp. 87-95.
[7] SYLLABUS (Autumn 1993) Europe Education Magazine, *Four Levels of Computer Use*, St, Albans, UK. Editor, John P. Noon, pp. 8-10

applicable to Product Design education. The four levels of computer use fall under the following headings: -

i) Enhancing existing materials and approaches

ii) Using existing software

iii) Adapting existing software and videodiscs

iv) Creating original courseware

i) Enhancing existing materials and approaches. In this 1st level of computer usage word processors and presentation software, such as PowerPoint, are utilised to create professional lecture notes and class handouts that can be electronically projected or distributed during classroom instruction. This is becoming standard amongst many Lecturers / Tutors and product design students for their design presentations and peer group assessment.

ii) Using existing software. The 2nd level of computer use is use of commercial software to assist in both your teaching and the students' learning. As product designers, we are increasingly reliant on this type of software across the complete design process, from a design tool to a prototyping tool. Examples include: - 2D and 3D CAD modelling, rendering packages for aesthetic appearance, diagnostic software, simulation, Finite Element (FE) analysis for the stress and deflection of the component, material selection and manufacturing software for CNC machining and rapid prototyping for component models. All BSc CAPD students are subjected to all this type of design software during the course.

iii) Adapting existing software and videodiscs. This relies on adding or altering available computer based materials to introduce content specific to the teaching approach or particular course. It is this approach which is used in the next heading (3.2 Utilising Parametric CAD As A Teaching Aid In Product Design).

iv) Creating original courseware. This 4th level involves developing your own computer-based instructional materials using authoring tools or a programming language. Developing these custom lecture packages often entails a group working over a network developing self-paced materials. This can be the most time consuming and costly to develop. It is under this computer level that the heading (3.5 The Broadnet Project For Learning And Teaching 2D CAD) best fits. It could however, be argued that it is a hybrid linking across level (iii) and level (iv), in that our own self paced computer-based instructional material works interactively with a commercial piece of software, in this case AutoCAD.

Heading (3.3 The Evaluation Of Videoconferencing In A Distance Learning Environment For Product Design) The BSc CAPD course, like other modularity courses in the University, was originally going to operate over a number of different campuses. Videoconferencing was seen as the communication link across different sites or any geographical distance, linking tutor with learner for support and using CAL and shareware software to provide an interactive link to discuss text or CAD drawings on screen in real time. A possible solution for product designers and engineers who work from different locations but need to communicate design with their peers.

3.2 Utilising Parametric Cad As A Teaching Aid In Product Design

This section of the chapter focuses on the evaluation and use of the software 'DesignView' tested by staff in 1993 and introduced in 1994 for the first time to students on the 1st year undergraduate course BSc Computer Aided Product Design within the Engineering Division at the University of Wolverhampton.

The prescribed programme of study has been developed on a progressive structure, establishing a foundation of study in Year 1 and then developing the subject disciplines through the subsequent semesters. Students entering the 1st year of the course are of mixed educational backgrounds and qualifications. In the past most students have passed the majority of modules. However, teaching problems have arisen, particularly in the number of students not associating the links between technical analysis and design. The increasing number of students who had enrolled on the course and other students who had chosen to study the module via the University modularity programme had also compounded this.

A possible solution, based upon the findings of [8]Hewitt (March 1992), was to integrate the software package "DesignView" as a teaching aid in the areas of Engineering Drawing and Technical Analysis, this was run in parallel to traditional teaching methods. Observations were carried out upon 1st year students who had experienced these teaching initiatives and an evaluation of the findings is documented in this section.

3.2.1 Student Profiles

An evaluation was carried out on 50 1st year students. The method was based on a questionnaire and observations. Following a pilot study on a number of students, the

[8] HEWITT, G, BYG Systems Limited. (March 1992) *Learning with Computers in Engineering - an Overview,* Conference proceedings (The Use of Computers in Engineering Education) presented for The European Society for Engineering Education, Nottingham Trent University., UK.

questionnaire [designed following guidelines described by [9]Guilford et al (1978)] was kept as simple as possible to mainly "Yes" or "No" responses. This enabled the questionnaire to be completed in the minimum of time. Each question was fully explained to the students prior to the survey to avoid any ambiguity on the students' part. An aim was to establish the student's educational backgrounds prior to entering the University, and highlight their comments on the tutoring methods and software used. This produced the following statistics: -

> 92% male, 8% female, 22% of students were classed as mature, ages ranging from 21 years up to 45 Years.
>
> Qualifications route on entering University, 52% 'A' Level, 34% BTEC, and 14% to include Access to Higher Education.

The students' backgrounds varied quite considerably from the point of view of age and previous learning experience, thus their study needs differed.

3.2.2 Evaluation Of 'Design View'

With reference to [10]'DesignView's user's manual (1992) the software was a computer aided design tool from Computervision Corporation operating in a graphics environment on a standard platform, namely an IBM-compatible 386 or 486 based computer under Microsoft Windows 3.0 or higher or a UNIX workstation. It could be linked with other Windows applications, such as Lotus 1-2-3, Microsoft Word and Microsoft Excel, thus charts could be created which could be dynamically updated to highlight any changes in the 'DesignView' drawing.

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[9] GUILDFORD, J. P. and Fruchter, B. (1978) Fundamental *Statistics In Psychology and Education*. Sixth Edition., McGraw-Hill.
[10] *DesignView, Microsoft Windows Version 3, User's Manual.* (1992) Computervision Corporation.

The software provided for variational design through a parametric system for producing design drawings and analysis. Based on dimension-driven variable geometry, the user could sketch the basic shape of the object. After specifying the dimensions the software automatically reshapes the object whilst maintaining relationships between the drawing elements. Other features of the software included: -

- Constraining the geometry using equations that are typed directly onto the design drawing.
- Mass Properties.
- Piece Part Design.
- Assembly Modelling.
- Kinematics.
- Geometric studies.
- Tolerance Analysis.

3.2.2.1 Students Use of 'Design View'

Students were introduced to 'DesignView' in the first year of the course, to supplement Technical / Engineering Drawing courses and provide a link between the technical analysis of design and drawing. With 'DesignView's' sketching features, drop-down menus and drawing tool icons, after a few hours tutorial students found the software easy to learn and use.

The technical analysis was restricted to the calculation of the second moment of area, or "I" values for symmetrical sections, and simple bending moments of beams and other components. Once the section or beam had been drawn and the appropriate formula built into the drawing, by changing the values the object could quickly be redrawn to its new size, and appropriate calculations produced.

Fig 3.2.1 and Fig 3.2.2 demonstrates the use of 'DesignView' in determining the " I" values of simply symmetrical sections, in this case the breadth 'B' = 60 mm and 'b' = 40 mm in Fig 3.2.1, have been altered to 40 mm and 20 mm respectively. Fig 3.2.2 shows the re-profiled section and the new value for the second moment of area "I".

Fig 3.2.3 and Fig 3.2.4 show 'DesignView's' application in the calculation of the bending moments of simple beams, in this case the load 'W' has been changed from 1000N in Fig 3.2.3 to 600N in Fig 3.2.4 and the new value for the bending moment produced. To complement the design process and assessment, students carried out a technical analysis on a product (for example a chair design) using 'DesignView'. The following list was given for students to consider: -

i) Produce accurate and well-documented drawings of the product.

ii) Check assumptions made on the types of structural materials used in the design and from this produce a list of material properties.

iii) Calculate the second moment of area, or "I" values for two symmetrical sections of the product.

iv) Calculate the compressive stresses in the main support members and the associated Factor of Safety.

v) Calculate the bending stresses about specified points, and possible areas of single and double shear stress.

vi) Comment on areas where torsional stress would have to be considered for the product.

This exercise proved successful in allowing the students to integrate design analysis with Product design.

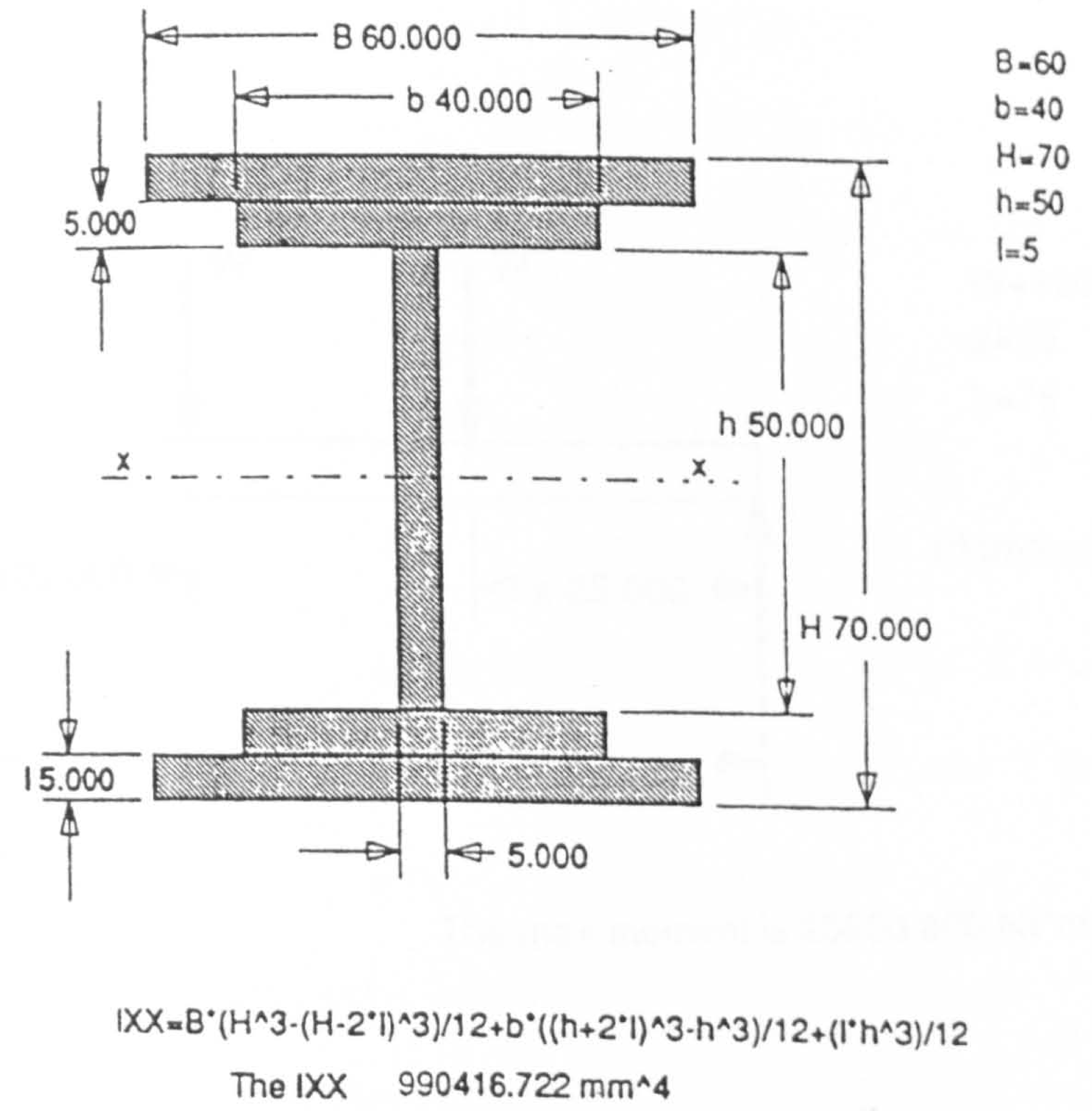

Fig. 3.2.1 **The use of DesignView for calculating the Second Moment of Area(I)**

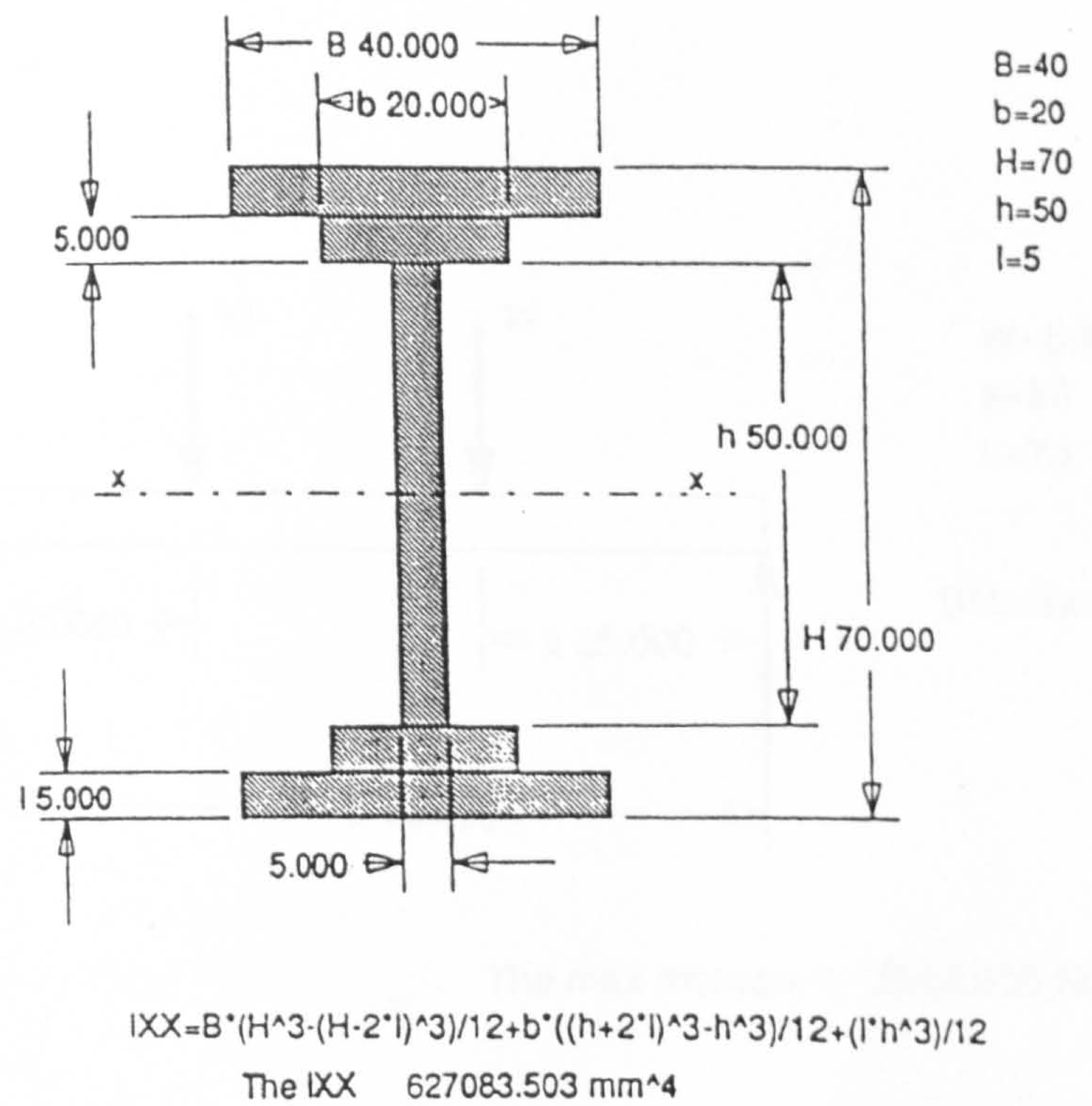

Fig. 3.2.2 **DesignView's re-profiled section showing the Second Moment of Area (I) after changes to values B and b**

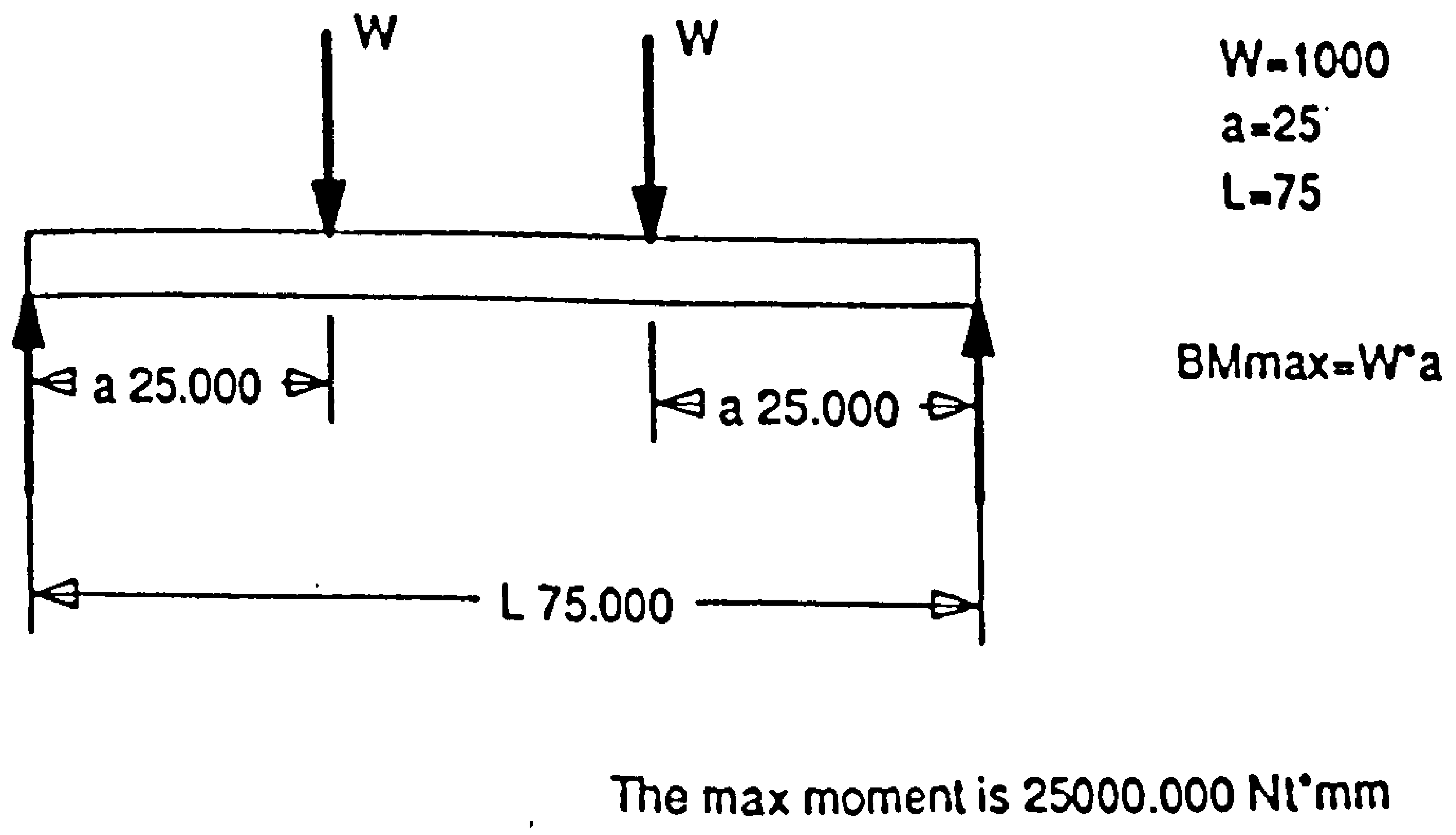

Fig. 3.2.3 DesignView's application in calculating the Bending Moment on a simple beam

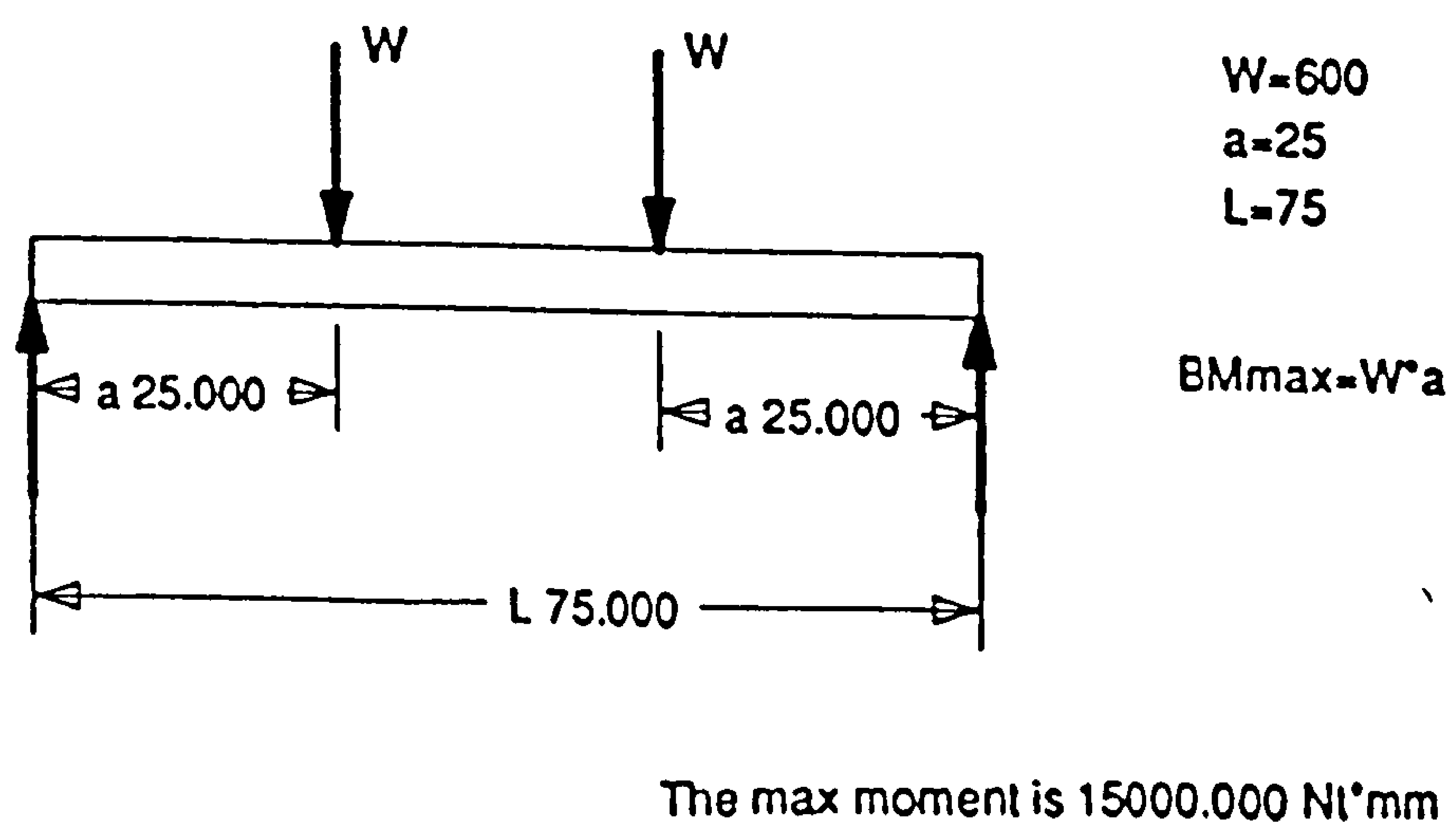

Fig. 3.2.4 DesignView's re-calulation of the Bending Moment after changing the value of load W

3.2.3 Student Responses to CAD and Technical Drawing Skills

The same 50 students were asked for their comments via the questionnaire regarding the role of manual drafting skills and CAD. This was considered significant as a result of the ever-increasing use of CAD in industry and findings by [11]Robertson et al (Sept 1991) who state that "Computer-Aided Design (CAD) systems can and should support and enhance the product development process". Robertson et al go on to say "CAD systems should help minimise the cognitive complexity facing the engineer, more specifically assist in managing design-related complexity and be easy to use".

All students experienced both methods of drawing in the first year of their course regardless of their backgrounds, whilst subsequent years of the course are predominantly CAD based. The following highlights students' responses to the questionnaire: -

a. Did you use computer software prior to University?	66% yes 34% no
b. Would you have preferred to be taught only a CAD drafting package rather than traditional drawing board skills?	65% yes 35% no
c. Do you feel traditional drawing board skills assisted you in learning the CAD package?	70% yes 30% no

d. Do you prefer technical drawing assignments by: -

i) CAD based	22%
ii) Traditional (on a drawing board)	16%
iii) Mixture of (i) and (ii)	62%

e. Do you feel CAD software has improved your technical drawing Skills?	32% yes 60% no 8% didn't know
g. Do you feel there is still a role for Technical Drawing skills?	94% yes 6% no

[11] ROBERTSON, D., ULRICH, K.T. and FILERMAN, M. (Sept1991) *CAD Systems and Cognitive Complexity: Beyond the Drafting Board Metaphor.* DE-Volume 31, Design Theory and Methodology, ASME, pp.77-83.

The findings from the evaluation revealed the surprising result that approximately one third of the students had not previously used any computer software. Often the assumption is made that students are computer literate on entering University, and this appears not always to be the case, a factor that needs to be taken into account for 1st year students.

With reference to the responses, 65% of students would have preferred being taught CAD compared with drawing board skills. This may be attributed to the fact that approximately 70% of the students had previously studied Drawing / Design to 'A' level or equivalent, with another 18% at GCSE level and, therefore, these students were already familiar with manual drafting.

Students who thought drawing board skills had assisted them in using CAD possibly saw the instructional benefits of manual drafting especially in the areas such as setting out drawings, construction techniques, size, and understanding the various views of orthographic projection in 1st / 3rd angle and isometric etc.

For assignments, 62% elected for a mixture of traditional drawing and CAD, only 16% selecting just the use of a drawing board and 22% purely CAD based. It is the author's view that this is a reflection of what students are initially at ease with. As students progress through the course they become more proficient in CAD by which time most students have their own drawing packages on their own computers.

Ninety four per cent of students saw the role of manual drawing skills as an asset. In product design this technique maybe used in the role of concept design, initial sketching and some rendering techniques whilst all dimensioned working drawings or 3D modelling would be CAD based.

In 'DesignView' the students initially worked from a booklet of text and standard drawing examples/tutorials, allowing interaction between student, booklet and computer. Tasks could be so arranged in 'DesignView' that allow students continual feedback on their performance, errors in defining constraints or over dimensioned component parts are indicated immediately on the graphics screen. With careful planning and documentation it could be argued that a package such as 'DesignView' could simulate a Computer Aided Learning / Computer Based Learning (CAL/CBL) environment. The added advantage is that at the end of the learning process the students will be extremely familiar with a commercially available CAD package.

3.2.4 General Conclusions

Part of the evaluation was based upon student responses with simple "yes" or "no" answers. The questionnaire was kept as simple as possible following a pilot study on a number of students. The results of the evaluation have shown that 'DesignView' benefited all students, in particular students with design flair but lacking good technical drawing board skills or design analysis. Overall the software gave a good insight into the role of Parametrics, and the integration between design and analysis. It is unfortunate that the software became incompatible with the latest computer operating systems and as such as been discontinued from the BSc CAPD curriculum.

Results at the time showed that the need for teaching engineering drawing using a drawing board is debatable. The increasing number of companies utilising CAD for design / layout drawings and the associated links in 3D modelling to CAM suggest that manual drawing board skills may best be used for initial concept design, sketching ideas and some rendering techniques.

The author would argue that 'DesignView' operating as described earlier in the chapter was indeed emulating a CAL/CBL environment. However, integrating a commercial CAD software with CAL under a windows type system with multi-processing would form the basis for the next development phase, and as such the proposal for the Engineering Broadnet project for Learning and Teaching 2D CAD came about. This is documented under item 3.5 of this chapter.

3.3 The Evaluation Of Videoconferencing In A Distance Learning Environment For Product Design

This section of the chapter focuses on the use of one to one Videoconferencing in the Engineering Department at the University of Wolverhampton. The University offered a Master of Science degree programme in Engineering Product Design which was operated in collaboration with Mikkeli Polytechnic, situated to the north of Helsinki in Finland. The majority of modules on the programme are taught in Mikkeli by lecturers from the University of Wolverhampton and the Finnish students that successfully complete the programme are awarded their degree by the University of Wolverhampton. The teaching methods employed on this programme were severely restricted by the cost of travel and accommodation for the lecturers, which has led to the modules being taught in a compressed format. Video conferencing was seen as a valuable tool in extending the range and effectiveness of teaching methods at relatively low cost and a trial programme to establish the acceptability and scope of this approach has been carried out.

This section reports on the execution and results of the trial programme and indicates areas in which video conferencing can make a significant contribution to the distance teaching of product design.

3.3.1 Structure Of The Course

The design profession is strongly influenced by the developments in the field of Information Technology and the application of Computer Aided Engineering (CAE). The use of computer packages is seen as significant to teaching and assessment in product design [12](Felton 1994).

[12] FELTON, A. J. *Evaluation of CAL in undergraduate courses*, Computer Aided Learning in Engineering Conference, University of Sheffield 5th-7th Sept 1994, pp. 313-322.

MSc Engineering Product Design [13](Award Handbook 1994-95) is a European post graduate course, one of the first of its kind whereby a student may study part, or all of the course in another European country. The course was designed in co-operation with several European educational institutions, but only became available in 1994/95 either in The University of Wolverhampton or the Hogeschool, Utrecht in Holland. The University of Wolverhampton, in collaboration with Mikkeli Polytechnic, offered this particular programme enrolling 18 Finnish students in the first year.

3.3.2 Background to Installation of Video Conferencing System

During 1994 / 1995 lecturers from the University of Wolverhampton Engineering school visited Finland for two weeks at a time on numerous occasions delivering modules to Finnish students including lectures, seminars and tutorials under the Masters Programme. This imposed quite a costly commitment by the institutions involved by way of travel and subsistence, and the accelerated teaching process over two weeks per module as opposed to four or five weeks naturally induces both physical and mental strain on the lecturers concerned as well the students. With the requirements to contact staff and students in the Finnish institution on a regular basis and to deliver in a cost effective manner, a decision was made to investigate Video Conferencing [14](Butters et al 1994) as a supplementary teaching aid and another communication option to be used in conjunction with existing fax, telephone and Email.

Video conferencing offered a low cost instant visual contact between separate parties. At that time experimentation using Intel's one to one ProShare 200 Video Conferencing System was taking place within schools at the University of Wolverhampton. Once an

[13] MSc / Postgraduate Diploma / Certificate in Engineerting Product Design. (1994/95) Award Handbook, University of Wolverhampton, UK.

[14] BUTTERS, L., CLARKE, A., HEWSON, T. and POMFRETT, S. (September 1994) *The Dos and Don'ts of Videoconferencing in Higher Education*, HUSAT Research Institute, Support Initiative for Multimedia Applications, SIMA Report Series Number 4.

ISDN link had been installed at the University of Wolverhampton and Mikkeli Polytechnic with the associated computer equipment and software, successful transmission of speech and video was established during November 94 between staff and students. During this first transmission the system was used mainly to rectify problems associated with enrolment forms for the Finnish students.

3.3.3 Implementation Of Video Conferencing System

Intel Proshare software [15](Intel 1994) at the time came in three editions. Standard Edition and Premier Edition operated between personal computers linked over networks and conventional telephone lines, and Proshare 200 system offered a video facility over an ISDN line.

3.3.3.1 Standard Edition

Features included: -

- On-screen notebook. This provided a shared medium for working together.
- Mark-up tools and pointers. Text tools, highlighters, and pens to assist in communicating with each other.
- Snapshot and document import. Import a multi-page document and transfer it into the onscreen notebook or take snapshots of Windows document.
- Shared OLE (Object linking and Embedding). Launch the source application, alter and update instantly the document in the onscreen notebook.
- Private space. For personal notes not visible to others.
- Print and save. Enabled you to print notebook pages or save your work.
- Only one copy required. LAN and Modem users can download Jump Start, to enable someone to receive a connection.

3.3.3.2 Premier Edition

This gave all the features of the Standard Edition plus: -

- Application sharing. Allowed interactive working, editing the same file within the original application.
- Address book. Can store and dial frequently called numbers.

[15] *Intel ProShare Personal Conferencing software, Users Guide*, (1994) Intel Corporation.

3.3.3.3 Proshare Video 200 System

This had all the application sharing capability of Premier with addition of video facility. The video system operated over two ISDN lines and came with its own camera which mounted on top of the monitor, ear piece with built in microphone, and boards which slotted into the personal computer. This particular system was used for the Wolverhampton / Finland connection.

3.3.3.4 ISDN Link

With reference to BT Customer Information document [16](ISDN2 1995) "ISDN2 provides two separate channels over a single telephone line and with appropriate terminal equipment provides a fast flexible and reliable way of sending and receiving voice, data, text and image communications across the public network, both in the UK and overseas ISDN's ".

3.3.3.5 System Requirements For Proshare 200 Personal Conferencing Video System: -

- PC with 486 33 MHz CPU minimum (higher performance Pentium Processor recommended)
- 16 MB RAM Recommended.
- DOS 3.3 plus Windows 3.1 or higher in enhanced mode.
- 17 MB of available hard disc space.
- VGA display with 256 colours or higher.
- ISDN link

3.3.4. The Trial Programme

Once the system had been established the following criteria, which represented the minimum requirement for distance learning, were used as a bench mark for development to evaluate how the system performed and the lecturers' and students' reactions to using this equipment.

[16] *ISDN2 Many applications; a single tool*, (1995) British Telecom customer information document.

3.3.4.1 Criteria for Evaluation

i) The system satisfactorily downloads text and graphics.

ii) The system should allow successful interaction on text allowing student's assignments to be down loaded from Finland to Wolverhampton enabling on screen interaction between lecturers and students.

iii) The system should be easily accessed and operated. The following were reviewed: -

(a) How do staff / students respond / react?

(b) Is it a difficult environment to work in?

(c) Reliability?

3.3.4.2 Range of applications

As previously discussed the system had been used initially for administration purposes to deal with student enrolment, whereby one could deal face to face with any associated problems of form filling and the course in general. This was followed by members of staff and students introducing themselves to one another prior to teaching new modules. The video conferencing equipment was used as a supplementary teaching aid in tutorials for modules of project planning, material technology for product design and a group assignment in the area of product material selection. Interactive discussion took place on the progress of student's assignments that were entered onto the screen. During the group project the lecturer concerned looked through the student's text and questioned details on the relevant topic area. For this to be effective it was suggested that bullet points be used to highlight the most relevant points for consideration, otherwise a considerable time maybe spent reading through a great deal of documentation.

3.3.5 Results / Evaluation Of The Trial Programme

The results and evaluation of the trial programme are set out under the following five sub-headings: -

3.3.5.1 System Evaluation

The video link provides visual contact and you can hear and see the person's responses. One lecturer commented on poor resolution of the video but did admit that he could recognise the students when they first arrived at the University of Wolverhampton; it could be argued, therefore, as being adequate. It is the author's opinion that, whilst screen resolution up to a certain level is largely due to the sophistication of computer and VDU being used, it is also advantageous to have good background and lighting for reasonable visual transmission. During transmission there was a slight time delay which can cause problems.

The system provided an ear piece with built in microphone for voice communication. When the sound is projected through two small speakers this allows other persons present to hear the conversation but can cause disturbance and feedback for the operators, especially with the added time delay. The use of headphones by the operator would assist in alleviating this problem. When dealing with overseas students with the added language barrier one tends to shout, a point one needs to be self conscious of.

The Finnish institution have mainly dialled Wolverhampton to establish the link since the University of Wolverhampton have had problems dialling Finland; a problem which cannot be explained.

3.3.5.2 Sharing Software Applications

Sharing applications such as text files in Word for Windows, Excel spreadsheets and transferring files (not sharing) worked well however, it is thought some problems associated with different keyboard drivers for the two countries produced strange characters at times.

3.3.5.3 Reaction of Staff

The videoconferencing system was designed for one to one and proved suitable for tutorial support. Feedback was good and lecturers in Wolverhampton have addressed 18 students at a time in Finland on general and teaching matters using the mentioned speakers, and 3 students at a time, with one controlling the equipment, for tutorials regarding group assignment work.

One lecturer pointed out that he disliked explaining assignments over the video conferencing network abroad, but prefers in the first instance to fax the assignments to enable students to read prior to discussion. Any relevant points or ambiguities can then be addressed during the video transmission. Fax, Email addresses and telephone still played an important role in setting up dates and times for videoconferencing transmission, especially with time differences between countries.

3.3.5.4 Reaction of Students

Initially the system required a fair degree of skill on the operator's part and the students who were keen were generally interested in the technology. Of the 18 Finnish students who took part only 2 disliked using it, stating they preferred the physical presence when dealing with people.

3.3.5.5 Evaluating the Criteria

Overall, the trial programme and system was deemed to be successful as a teaching medium when measured against the criteria as previously stated.

3.3.6. Further Applications

3.3.6.1 Multi-Site Nature of University

With the main campus in the heart of Wolverhampton, and sites at the Science Park Wolverhampton, Compton campus 3 miles away, Telford campus in Shropshire 20 miles away, Walsall campus 15 miles away and Dudley campus 4 miles away, the geographical status at the University of Wolverhampton with its modular degree scheme and computer network across sites make it an ideal target for Video Conferencing.

Desktop Video Conferencing would normally be suitable for informal personal communications between sites. However, in the case of formal meetings with a number of participants involved, dedicated studio settings would need to be considered. With reference to the survey and report by [17]Carter et al (1996) "Computer-based desktop Video Conferencing systems require less financial cost and also require less in terms of management and support. They are likely to be funded and used by a single department for research or collaborative work. Larger-scale videoconferencing has required shared funding and has provided shared resources being beyond the budget of single groups or departments".

3.3.6.2 Use over Network

The premier edition without the video link has been used by the engineering department inter-site between Wolverhampton and Telford, using local area network (LAN) and internal telephone link in the areas of the Product Design curriculum. This has included similar examples to the trial programme above, sharing graphics and text interactively including limited success in sharing design drawings within a Computer Aided Design

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[17] CARTER, C., CLARKE, A., GRAHAM, R., and POMFRETT, S. (April 1996) *The Use of Video Conferencing in Higher Education*, SIMA Report Series Number 20, pp.26 -27.

(CAD) package (reference Fig 3.3.1 and Fig 3.3.2). This system has the advantage of reduced cost over the network and no telephone bills when using internal lines.

3.3.6.3 Use over the Internet

Evaluation in using videoconferencing for Product Design via the Internet using CU-SeeMe, a desktop videoconferencing program offers to provide useful conferencing at minimal cost, [18]Clark et al (1995).

3.3.6.4 Undergraduate Courses

For undergraduate courses in Computer Aided Product Design it is envisaged that interactive tutorials with students using CAE, CAL and CAD packages could become the norm across remote sites. Students down load CAD assignments, Lecturers determine if they can drive students' design drawings making modifications and recommendations, to include comments such as highlighting bad design features, high stress concentrations etc, or provide tutorial support to the remote learner.

3.3.6.5 Links with industry

The technique of sharing CAD data between centres using videoconferencing techniques and shareware software is starting to be accepted by industry, often known as Collaborative Engineering. This offers a quicker response time by designers/engineers to 2 dimensional and 3 dimensional design data and reduced lead times for new products being introduced. This opens new avenues for industrial-based projects providing a link between University courses and industry.

[18] CLARK, S., MAHONEY, G. and SCRIVENER, S. (July 1995) *A Study into Video Conferencing Using the Apple Macintosh Platform.* Support Initiative for Multimedia Applications, SIMA Report Series Number 14.

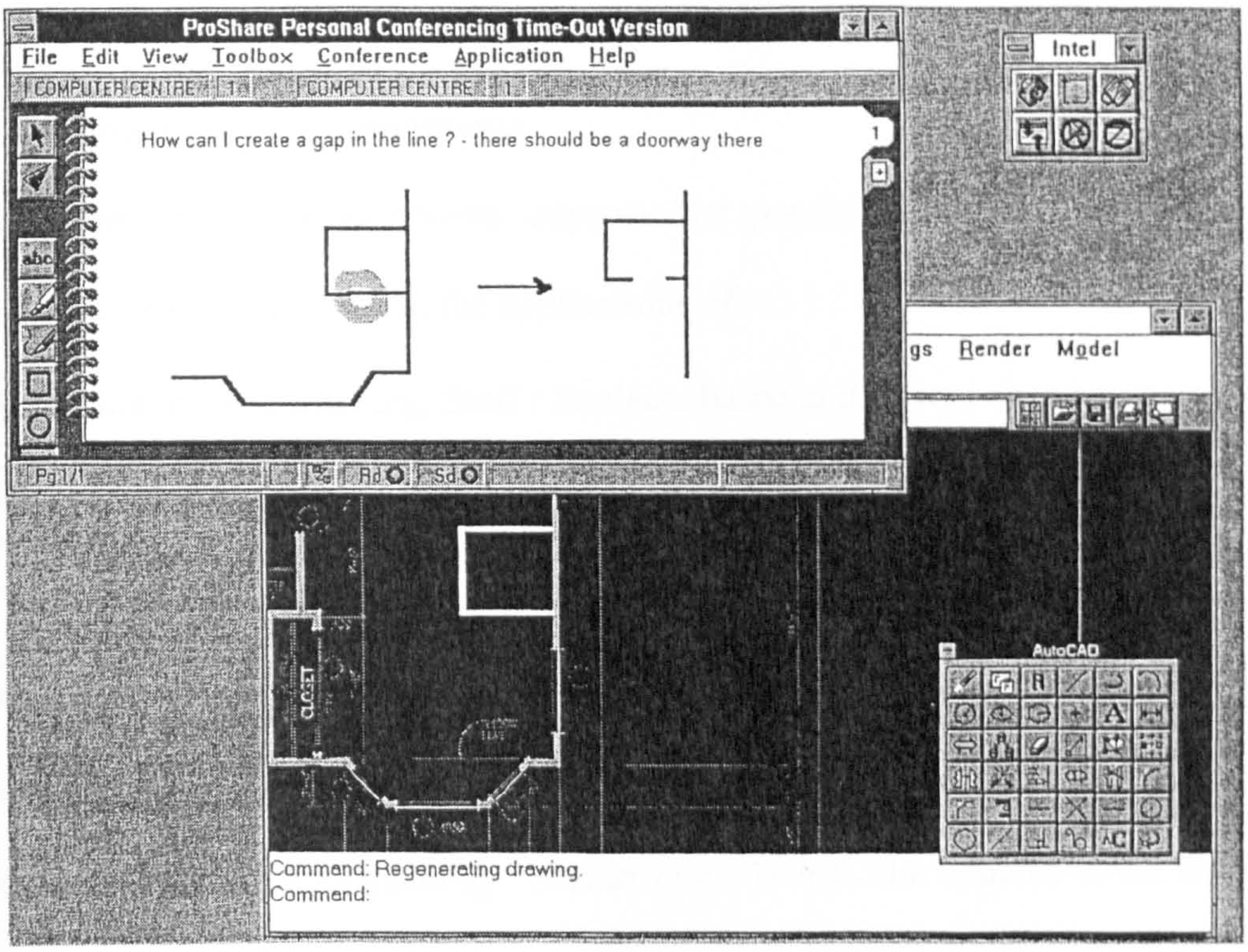

Fig. 3.3.1 Sharing a CAD application interactively, highlighting the use of the notebook by user 1 to prompt user 2 for an answer

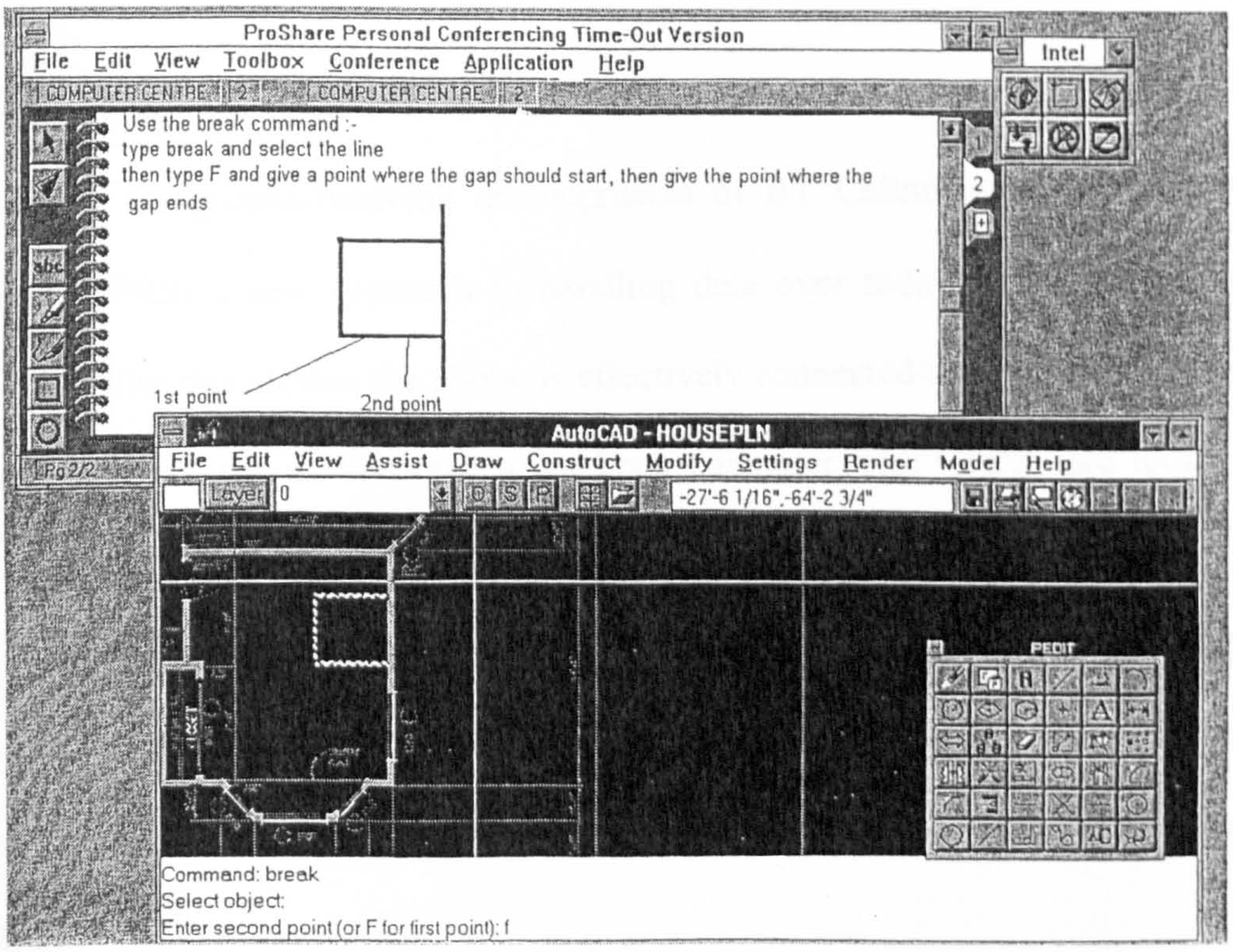

Fig. 3.3.2 Sharing a CAD application interactively, response from user 2

3.3.7 Possible Future Developments

As software and IT developments improve the possibilities would appear endless. Future developments may lie in the applications of: -

- Education, remote teaching, Staff / Students based at different sites home or abroad.
- CAL / CBL packages and tutorials.
- Remote fault diagnosis.
- Demonstration of software.
- Continuing Professional Development (CPD), in company training.
- Interviewing staff / students.
- Sharing interactively CAD data.

At least one institution was considering skills training courses for teachers who could soon teach via Videoconferencing [19](Carter et al. 1996). The courses cover three main skills: -

- teaching in front of a camera
- visual aids for Video Conferencing and
- handling interactive Video Conferencing (e.g. students questions)

[20]Hewson (14th May 2000) in 'THE SUNDAY TIMES' newspaper carried an article discussing the ground-breaking developments of BT Cellnet's general packet radio service (GPRS) a new approach to handling data over today's digital mobile phone systems. With this service the phone is effectively connected to the network constantly, email messages turn up instantly, a notebook computer with GPRS card looking at an internal Web page could update a document immediately.

The shape of things to come is shown in the form of a small videoconferencing phone from the company 'Ericsson' which can sit on the desktop, and works by either voice recognition or the touchscreen, a small rotating camera provides the videoconferencing link.

[19] CARTER, C., CLARKE, A., GRAHAM, R., and POMFRETT, S. (April 1996) *The Use of Video Conferencing in Higher Education*, SIMA Report Series Number 20, pp.26 -27.
[20] HEWSON, David. (14th May 2000) THE SUNDAY TIMES. 'Mobiles moving upwards again'. UK, p.11.

3.3.8 General Conclusions

Video conferencing can play a vital role as a communication tool for a variety of purposes. [21]Braham (1991) stated "What the fax did for business in the 1980's, video conferencing promises to accomplish in the 1990's and engineers are among it's principal beneficiaries". Video conferencing offers relative low-cost instant visual contact between separated parties across buildings or countries.

Generally both staff and students could see the potential of using videoconferencing as a supplementary teaching aid in a distance learning environment.

With careful planning and preparation utilising the video conferencing system, telephone, fax, and Email it would be possible to deliver the same MSc programme as discussed or other similar programmes with reduced tutoring and travel cost. A programme may consist of one week of lectures based in the other country accompanied by a second week of tutorials at Wolverhampton University via link with the second party.

[21] BRAHAM, J. (May 9th 1991) *Captains of Video*, Journal-Article; Machine-Design, pp.71-75.

3.4 Characteristics In Developing A Computer Aided Learning (CAL) Package For Product Design

The following listing of characteristics of good software design and guidelines relating to the design of an effective user-interface in the context of CAL packages are well documented by [22]Anumba (September 1994) and [23]Onwubiko (1989), who identified many of the characteristics as being desirable in computer-aided design (CAD) systems. Fig 3.4.1 shows a block diagram of these proposed characteristics under the area of 'General Considerations' and 'User Interface Considerations' that were taken into account when developing the Engineering Broadnet Project for Learning and Teaching 2D CAD which is documented in the next sections of this chapter (3.5 and 3.6).

3.4.1 The General Considerations Or Key Characteristics Of A Good CAL Package

The general characteristics are essential features of a good CAL Package: -

- Efficiency – the performance of the program should exploit the full capability of the system, in maximising computer memory and resources such as time for student, and lecturer, speed of response should be fast and consistent. But not so large or expensive as to limit their use.
- Flexibility – how easy is it to make modifications to the software due to changes imposed from the user or system operation.
- Recoverability – CAL packages should be tolerant of misuse by the user (Students) without 'crashing'

[22] ANUMBA, C. J. (Sept 1994) *Enhancing Student Experience Of Computer-Aided Learning Packages.* The Proceedings of a Conference on Computer Aided Learning at the Universty of Sheffield in association with CTI Centre for Engineering. England. pp.341-349
[23] ONWUBIKO, C. (1989) *Foundations of Computer-Aided Design*, West Publishing Company, St Paul.

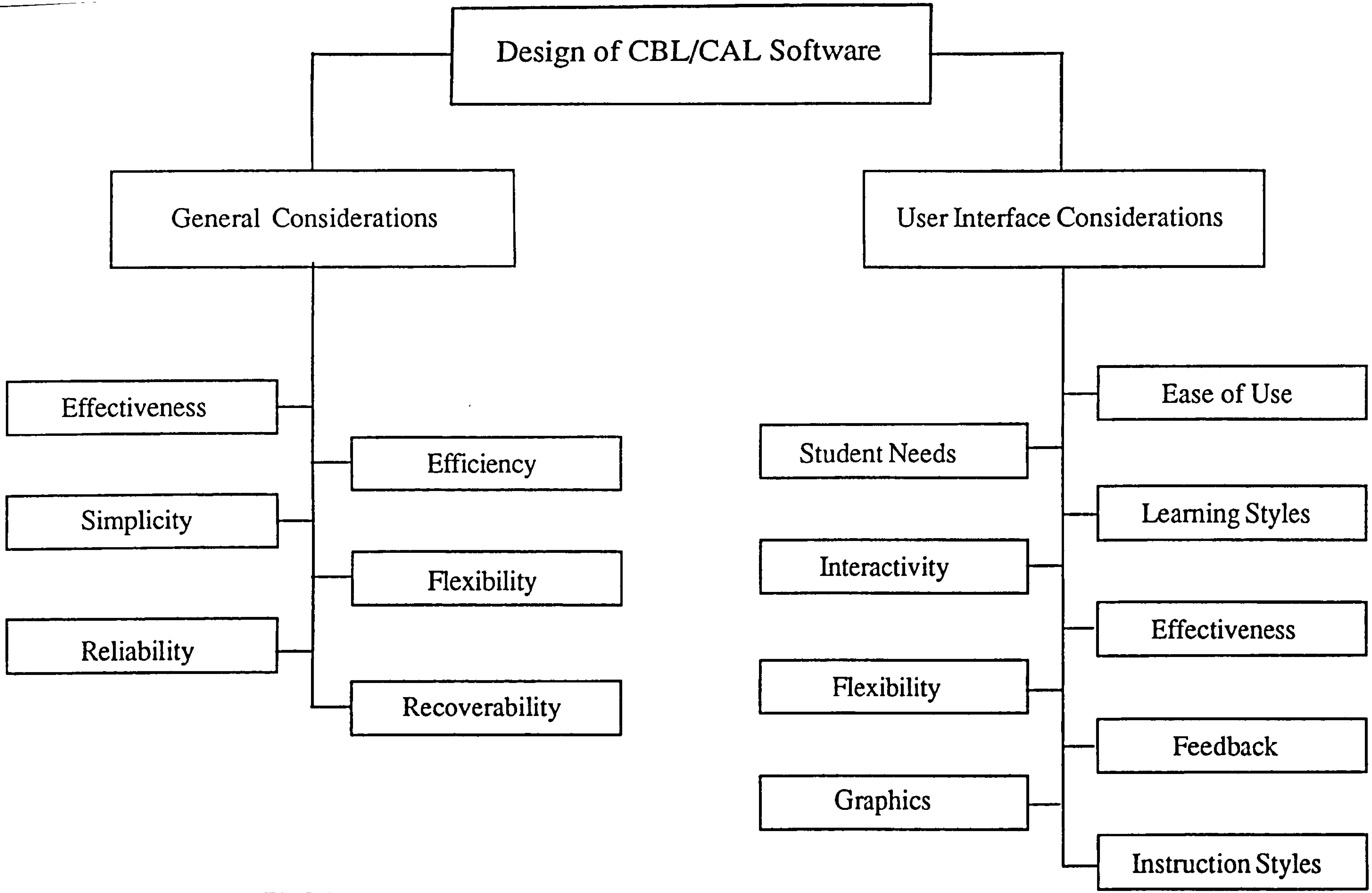

Fig 3.4.1 Design of CAL Packages – Performance Indicators

- Effectiveness –as a teaching/learning aid how well the CAL software achieves its primary function.
- Simplicity – the package should not be complex in design thus affecting its acceptability and usability.
- Reliability – the package should operate in a consistent and predictable way, producing consistent valid results.

3.4.2 User Interface Considerations

The design of the user-interface is important to enhance the student's experience of the package. The following guidelines should therefore be considered: -

- Packages should be easy to use - essential if to be acceptable by students. If difficult to use students become frustrated and lose concentration.
- Student needs and preferences should be taken into account. In the past very few of these end-users are consulted at the development stage. In the Broadnet 2D CAD package students were involved from the start through to its evaluation. For greater effectiveness and acceptability, student involvement in the development of packages should be actively sought and encouraged.
- Learning styles - different learning styles and paces should be supported. Many authors argue that the computer is ideally suited to catering for individual differences. The design of CAL packages should allow students to work at their own pace and should, to a certain degree, accommodate different styles of learning.
- Interactivity - It is essential that CAL packages exhibit a high level of interactivity to foster active student participation in the learning process. It is no good the students sitting there while the computer does all the work.

- Effective user-interface - The student should be able to follow and understand what the system is doing. A help facility is considered useful in effecting this.
- Flexibility - To enhance the quality of the user-system interaction a flexible user-interface is important in accommodating the needs and preferences of different students. The flexibility offered could relate to the level of assistance available to the student, the actual screen layout, and the range of input and output facilities available.
- Feedback - should be clear and concise to the student at all stages. Help messages and prompts for user-input should relate to the specific tasks in hand and to enable the student to continue his/her work.
- Graphics and visual presentation - images, and animations often enhance student understanding compared with continuous written text or continuous verbal dialogue.
- Instruction Styles - it is suggested that open, student-centred and didactic (designed to instruct) styles of instruction should be accommodated.

3.4.3 Meeting The Learning Criteria

In developing the Broadnet Learning and Teaching package a certain number of learning criteria had to be satisfied and to this end the content of the package was developed around a number of CAD module guides. All students receive a copy of these at the start of the module, as previously discussed under the chapter sub-heading (2.3.3). The student therefore knows the 'Aim' of the module, the assessment components to pass the module and the 'Learning Outcomes' on completion of module in terms of: -

- SUBJECT SPECIFIC OUTCOMES (SSO)
- PERSONAL TRANSFERABLE SKILLS (PTS)
- GENERIC ACADEMIC OUTCOME/CRITERIA (GAO/C)

A copy of the CAD Fundamentals module guide is included on the next three pages for reference. From this it can be seen that the package would support Lecture 5 to Lecture 11 and help meet (SSO outcome (i)), (PTS outcome 1 and 2) and (GAO/C outcome A, C, and F).

Module	**CM1004 CAD FUNDAMENTALS**		
Semester 1			
Pre-requisite:	None	Co-requisite:	None
Level:	1	Credit Value:	15
Timetable Slot:	WED Telford	Location:	
MODULE LEADER:	Room Tel		

Aim: To give a good knowledge and understanding of the capabilities and application of specific CAD software.

Outcomes: On completion of the module a student should be able to:

SUBJECT SPECIFIC OUTCOMES (SSO)

OUTCOME (I):	Develop CAD presentations in line with standard orthographic projections.
SCOPE:	First/Third Angle Projection, Layer control, Isometric Projections.
ASSESSMENT COMPONENT(S):	Components 1 & 3

OUTCOME (II):	Integrate graphical data from dissimilar systems.
SCOPE:	Vector and Raster based images, File Conversion, Scanning Techniques, DTP,
ASSESSMENT COMPONENT(S):	Component 2

PERSONAL TRANSFERABLE SKILLS (PTS)

OUTCOME 1:	(4) Use Information Technology
SCOPE:	Develop presentation techniques in CAD and Desk Top Publishing/Word Processing
ASSESSMENT COMPONENT(S):	Component 1 & 2

OUTCOME 2:	(1) Communicate Effectively
SCOPE:	Visual and written communication
ASSESSMENT COMPONENT(S):	Components 1, 2 & 3

GENERIC ACADEMIC OUTCOME/CRITERIA (GAO/C)

OUTCOME A:	(A) Make Use of Application Software
SCOPE:	Utilise CAD and support software in an effective manner
ASSESSMENT COMPONENT(S):	Component 1, 2 & 3

OUTCOME B:	(C) Evaluate and Appraise
SCOPE:	Apply standard procedures to given situations
ASSESSMENT COMPONENT(S):	Component 1

OUTCOME C:	(F) Think Creatively
SCOPE:	Develop design solutions for limited problems.
ASSESSMENT COMPONENT(S):	Component 1

Tuition:	1 hour lecture and 2 hours tutorial/workshop per week.
Private Study	7 hours per week
Teaching Methods:	A combination of short lecture based introductions with "hands-on" exercises/practicals. Computer based demonstrations and practical exercises.

LECTURE PROGRAMME:

Lecture	Title or Topics Covered
1	File types and file manipulation: directory structures
2	Introduction to Word-processing and Desk Top Publishing - incorporating graphics. Printing/plotting.
3	Image scanning and graphic file formats.
4	Raster versus object based drawing packages.
5	Introduction to Computer Aided Design. Opening/closing files - basic entity control.
6	Co-ordinate systems
7, 8, & 9	Drawing conventions - orthographic projection. CAD transformations.
10 & 11	Line styles and dimensioning techniques
11	Geometric transformations e.g. mirroring.
12	Isometric views.
13	Module review.

ASSESSMENT: The overall grade is determined by weighting the elements of the assessment into three components as follows:

	ASSESSMENT COMPONENTS					
	DESCRIPTION	OUTCOMES			PASS/ FAIL *	WEIGHTING *
		SSO	PTS	GAC		
1	Component 1: CAD based design problem	I	1,2	A, B, C		35%
2	Component 2: Manipulating graphical images	II	1,2	A		30%
3	Component 3: Written Assignment (Orthographic Projection)	I	2	A		35%

To pass the module it is normally necessary to achieve a minimum grade of D5 in **each** of the three components of the module as shown above.

Any written work for assessment should be handed in to the Registry Point by the due date, as indicated by the Lecturer, and a dated receipt obtained.
If you have a valid reason for late submission then **written** permission must be obtained from the Module Leader **before** the due date on form AAO33.

PRIVATE STUDY TIME

Each week you will need to tackle some practical element relating to the use of CAD. The work given for completion is intended to enhance the core lecture material and to provide a sound practical experience of CAD.
The guided reading given below, offers the opportunity to either do some background reading around the subject or as a source of reference for further examples or further guidance in a particular topic.

GUIDED READING:

There is a large selection of texts on MSDOS, File Transfer, Word-processing, CAD packages AutoCAD etc available, many of these can be found in the Learning Centre. In the main these will provide useful sources of support material.
Manuals may also be borrowed for a limited period.

PS You are reminded of the importance of checking that you are officially registered for this module otherwise you will not be awarded a grade.
You are also reminded of the consequences of cheating/plagiarism.

3.5 The Broadnet Project For Learning And Teaching 2D CAD

Broadnet was an Internet based service network for the West Midlands region of the United Kingdom aimed at supporting the regional business community. It provided a number of services ranging from the University of Wolverhampton accredited on-line training modules to information at local, regional, national and international levels. The Delta Institute within the University of Wolverhampton in partnership with ICL Education systems and Telewest Communications developed Broadnet.

With reference to [24]Molyneux (1999), in the Project Broadnet summary disseminated to the International World Expo 2000 committee, which Broadnet had achieved World Expo 2000 status the following statements are made: -

"In the Victorian age the region around Wolverhampton known as the Black Country prospered as a result of major advances in transportation. Railways and canals created the infrastructure to enable the engines of the industrial revolution to move their products to market. Such communication and transportation links were vital to their success. Today a new system of 'information highways' is set to repeat the success of the last century. These electronic canals were part of the vision of Steve Molyneux, IBM Professor of Interactive Communication Technology at the University of Wolverhampton that has taken shape under the name of Broadnet".

"In order to meet the demands of the next millennium, the technology in use is a highly organised broadband network connected to a media server. The high storage capacity of 256 Gigabytes of the server, allows it to hold all the Broadnet services and its harnessing of the equivalent of 64 Hypersparc stations running in parallel make it one of the most powerful systems today. In addition the server also acts as an access point into

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[24] MOLYNEUX, Steve. (1999) Project Broadnet \ Innovations. University of Wolverhampton, The DELTA Institute, England. p.1

the Internet for users. The server is also capable of storing over 150 hours of broadcast quality video, which is delivered over the Broadnet network. The services Broadnet offers include lifelong learning materials, business directories, forums and on-line chat as well as hosting over 400 local company and other organisations web sites".

"Learning material is created by a number of faculties within the University of Wolverhampton and is delivered using an advanced 3rd generation on-line learning and support environment developed by the University. The system is capable of delivering high-quality learning materials to standard personal computers on the network and to digital Set-Top-Boxes in the home".

It was within this Broadnet framework of facilities that the Engineering CAD training package was developed to provide on-line learning and training in 2D AutoCAD.

3.5.1 Proposal For Developing The 2D Cad Training Package

The Engineering section of the University of Wolverhampton provides a number of CAD related modules within its subject disciplines i.e. Principles of CAD, CAD Fundamentals and CAD applications. These form the basis of 2D CAD and Graphical Modelling, and Advanced Modelling, which build on these modules using 3D CAD software. AutoCAD was the main software used for teaching 2D CAD and Pro-Engineer was the main package in use for teaching 3D modelling because of their wide usage in industry.

In 1996 the Author submitted a proposal to develop a CAD training package under the Broadnet umbrella, at the time very little if any on-line CAD training was available. This was because the module Principles of CAD attracted over 100 students per year across the University, and the BSc CAPD course operated across a number of campuses. To learn the software efficiently, small groups of twenty students at a time were taught; requiring extensive hands-on computer based tuition endorsed by a set number of lectures to facilitate the learning outcomes. In providing this service five members of lecturing staff were required, repeating the same lectures and computer based assignments because all students could not be accommodated at the same time.

The proposal was split into two sections, one to provide multi-media based teaching materials for 2D CAD and the second to develop distance learning techniques in the CAD field.

The proposal aimed at developing computer based learning resources and tutorials for the learning and teaching of the basic use of AutoCAD. The material would be accessed across the local computer network, or if necessary packaged in CD-ROM format. It was envisaged that the package would encourage a high degree of independent learning by the user, allowing more effective use of staff time in a University environment and enabling cost effective on-site training in companies if required. When used across remote sites in a distance learning environment the necessary tutorial support and counselling could be provided through video conferencing and share-ware software, the principles of which have previously been discussed, although this has not been necessary because BSc CAPD students have since been based on one campus.

3.5.2 Development Of The 'Computer Aided Design – Engineering' Training Package

In developing the Broadnet module 'Computer Aided Design – Engineering' 2D CAD training package for learning and teaching basic AutoCAD, important lessons had been learnt from previously developing a teaching and learning package for 'sketcher', the sketching package within the software Pro/ENGINEER.

The Pro/ENGINEER family of design tools has already established itself as one of the desirable software solutions in product design by many UK companies. It is a parametric, 3D feature based modelling system for the design through documentation of parts and assemblies. ProEngineer software, like many of its counterparts, is constantly being updated and refined and consequently new versions are distributed, on average twice per year. Because our training package for ProEngineer relied on the use of the menu structure within the software, once a new version came out our training package became obsolete very quickly or required major redevelopment.

It is because of this that anyone who regularly uses Computer-Aided Design will be aware of the rapid turn-around of new software, so rather than being aimed at a specific release of AutoCAD, the Broadnet 'CAD-Engineering' on-line AutoCAD training program would provide general training for any version. This statement appears in the module summary once the user enters the training program.

3.5.2.1 Accessing The 'Computer Aided Design – Engineering' Training Package

The 'CAD-Engineering' on-line AutoCAD training program is accessed via the University of Wolverhampton home page, Broadnet or WOLF (Wolverhampton Online Learning Framework), On-line training, Computer Aided Design – Engineering. Obviously the user also needs the AutoCAD software installed on their machine.

The program is based upon a series of tutorials that run through the user's Internet browser. To begin with they learn about various commands and general use of AutoCAD from within the Activities screen. They then have the opportunity to follow on-line exercises with the AutoCAD Assistant, a new window that is designed to run alongside AutoCAD. Fig 3.5.1 shows a screen shot highlighting the Activities screen whereby information regarding the nine tutorials is made available within the activity window: -

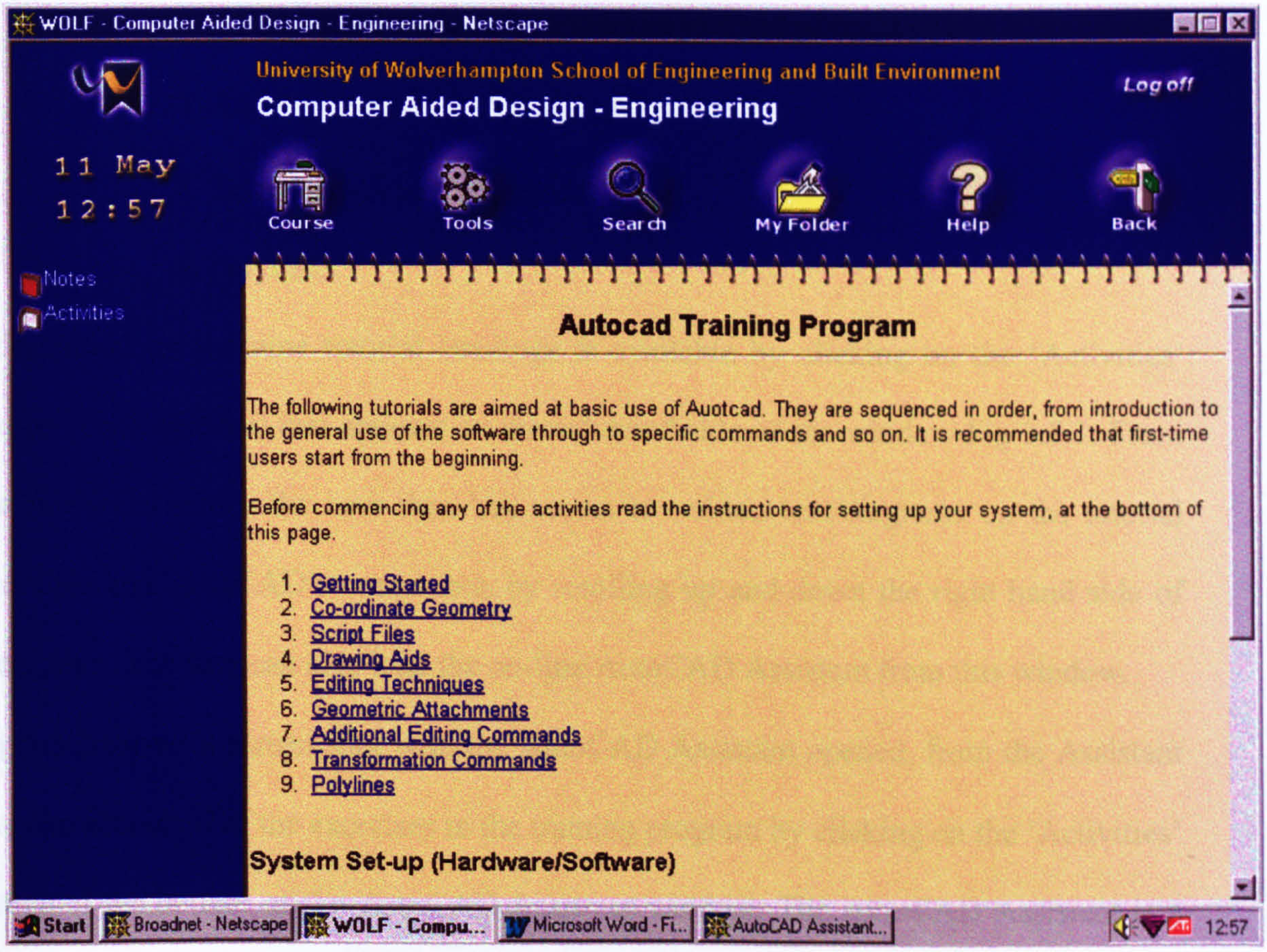


Fig 3.5.1 Screen Shot, Highlighting The Engineering Broadnet CAD Training Program Activities

1. Getting Started
2. Co-ordinate Geometry
3. Script Files
4. Drawing Aids
5. Editing Techniques
6. Geometric Attachments
7. Additional Editing Commands
8. Transformation Commands
9. Polylines

Information on the nine tutorial headings is available by clicking on the 'Activities' button (book symbol) that appears on the left-hand side of the window Fig 3.5.1. From the Activities screen the user then has access to written text/diagrams on the tutorial exercises and AutoCAD's commands by scrolling up and down the right hand side of the screen. The user can also load the on-line AutoCAD Assistant from this window.

Fig 3.5.2 shows a screen shot with the AutoCAD Assistant opened, from the Assistant you can access all of the exercises in the training program by clicking on the 'Activities' button at the bottom of the AutoCAD Assistant window. The AutoCAD Assistant is a browser window containing html documents and programmed using Java Script. It has been designed so that it occupies about a quarter of the screen, allowing the user to run AutoCAD software itself in the other three-quarters. This technique enables the user to follow the on-line exercises step by step (Fig 3.5.3) without having to keep changing the window, which is currently displayed - both can occupy the display area at the same time. The user can revert back to the previous page if required by clicking on the 'Back' symbol that appears towards the top right of the window.

Before commencing any of the activities the user is told to read the following

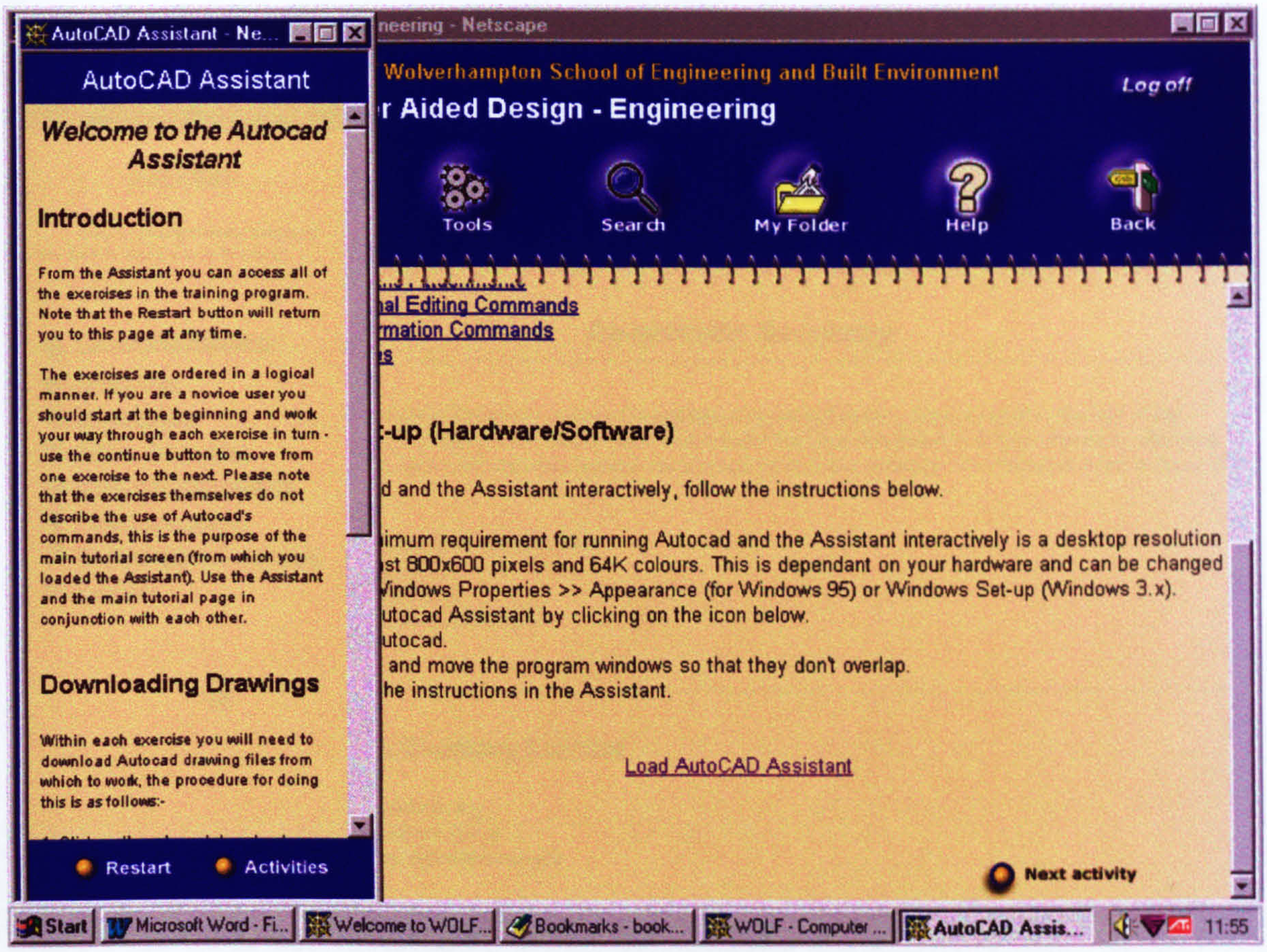


Fig 3.5.2 Screen Shot, CAD-Training Program With The AutoCAD Assistant Browser Window Opened

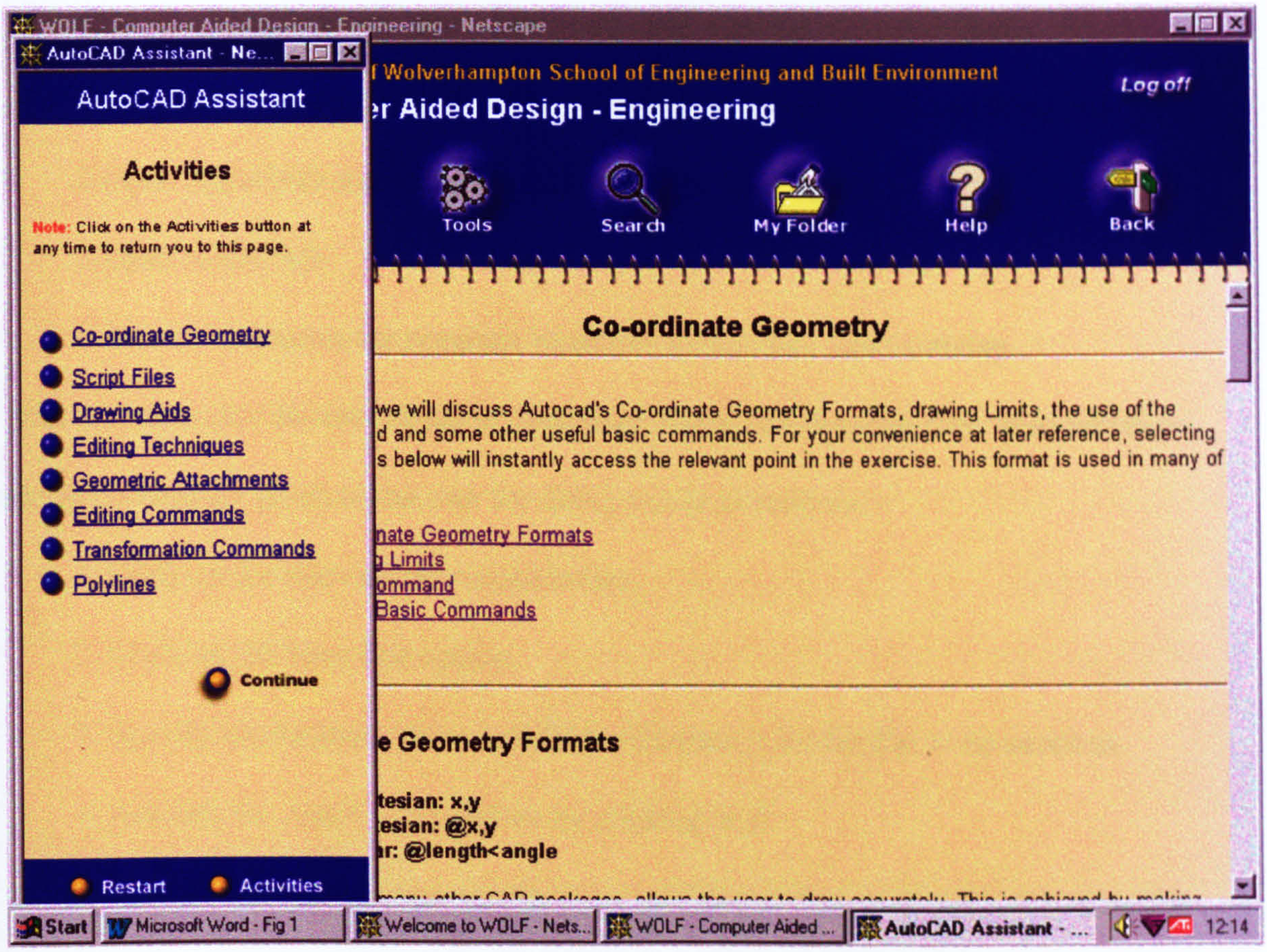


Fig 3.5.3 Screenshot, Highlighting The CAD Activities Accessible To The User

instructions for setting up their system: -

System Set-up (Hardware/Software) to use AutoCAD and the Assistant interactively, follow the instructions below.

1. The minimum requirement for running AutoCAD and the Assistant interactively is a desktop resolution of at least 800x600 pixels and 64K colours. This is dependent on your hardware and can be changed under Windows Properties >> Appearance (for Windows 95) or Windows Set-up (Windows 3.x).

2.Open AutoCAD Assistant by clicking on the icon below.

3.Open AutoCAD.

4.Re-size and move the program windows so that they don't overlap.

Within each exercise the user needs to download AutoCAD drawing files from which to work, the procedure given to the user for doing this is as follows: -

1. Click on the relevant download button.

2. Click on the Save File option.

3. Specify the location (drive and folder/directory) for the file to be saved to.

4. Activate the AutoCAD window by clicking in it.

5. Use File > Open then select the downloaded file to invoke the drawing exercise.

6. Use View > Zoom > All to maximise the drawing in the AutoCAD screen.

7.When you are ready to start, click on the Activities button below to access the menu of tutorials available.

Broadnet's increased bandwidth facilitates fast downloading so that they can access the drawings, as well as the tutorials, quickly. To make things run smoothly it is important to make sure that each time the user downloads they do so using the same directory/folder, it is recommended that they set up a new directory/folder for this purpose. When the example drawing is downloaded from the Broadnet server it is saved in the directory/folder as a (Filename.DWG) i.e. W.DWG; this can then be opened in the AutoCAD software.

Fig 3.5.4 shows a screen shot highlighting the AutoCAD Assistant and AutoCAD software running simultaneously. The 'Download' button can be seen at the bottom of the AutoCAD Assistant window. In this case the drawing example is W.DWG which has been downloaded to a directory/folder and then opened within AutoCAD as shown. The user is now free to work in AutoCAD on the example drawing whilst reading instructions from the AutoCAD Assistant window.

Fig 3.5.5 shows a screen shot of another tutorial example for using the 'Move' command which has been downloaded and then opened within AutoCAD. At the end of the tutorial session the user has the facility to either return to the Activities listing to carry out further tutorials by clicking on the Activities button at the bottom of the AutoCAD Assistant window. Or the Restart button will return the user to the start of the program.

3.5.3 The Tutorials 'Computer Aided Design – Engineering' Training Package

A copy of the drawing examples developed and held on the Broadnet server for downloading is included in Appendix III title: 'AutoCAD Training Document'.

From basic principles through to more advanced functions, the easy to follow exercises provide the user with a base on which to build their AutoCAD skills. After completing the tutorials, the user is encouraged to look at the references section which is included on the site, where they can find several publications that are recommended for additional information and further drawing exercises.

A Feedback option was built into the program to let us know how the student or users

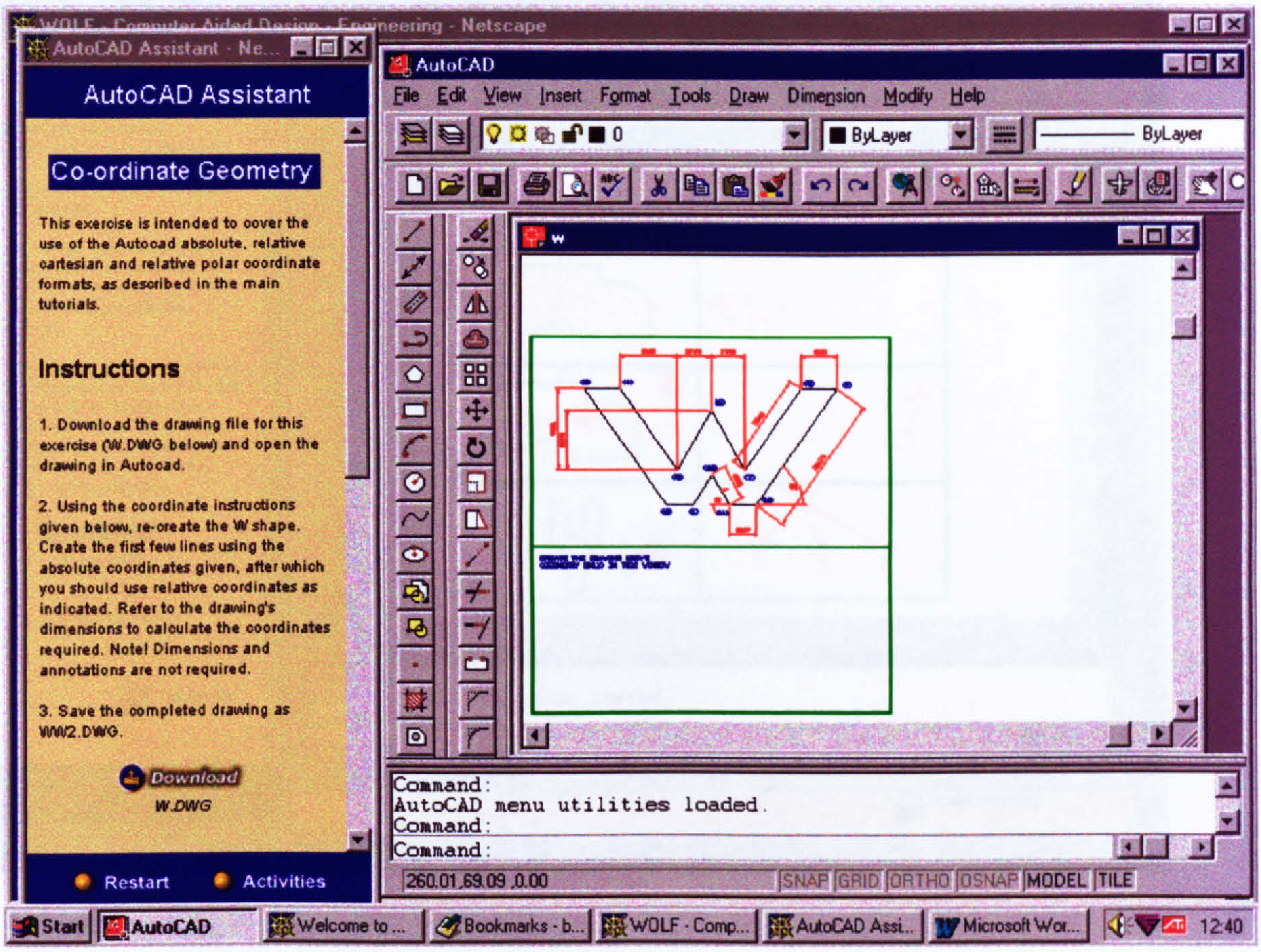


Fig 3.5.4 Screenshot, Showing AutoCAD Assistant And AutoCAD Software Running Simultaneously

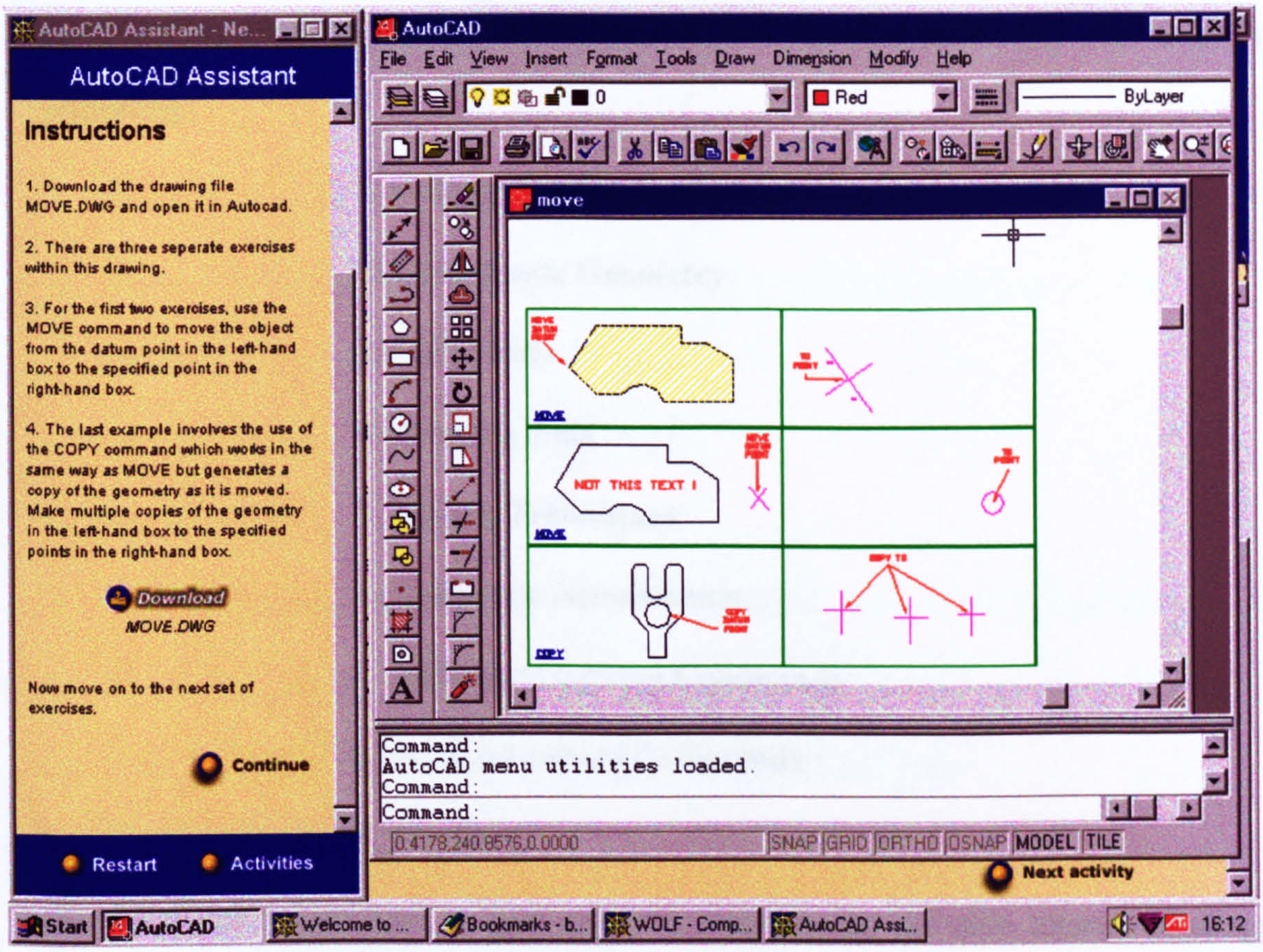


Fig 3.5.5 Screen Shot, Showing User Instructions And Downloaded Drawing In AutoCAD From Broadnet Server Via AutoCAD Assistant

were getting on, along with any comments good or bad regarding its contents and use. This proved invaluable in the early stages when proving the software operation i.e. identifying any links that did not work, ambiguities or irregularities etc.

The following nine tutorial headings were aimed at the basic use of AutoCAD. They are sequenced in order, from introduction to the general use of the software, through to specific commands and so on. It is recommended that first-time users start from the beginning.

1. **Getting Started**
2. **Co-ordinate Geometry**
3. **Script Files**
4. **Drawing Aids**
5. **Editing Techniques**
6. **Geometric Attachments**
7. **Additional Editing Commands**
8. **Transformation Commands**
9. **Polylines**

The following information is built into the program for the nine tutorial headings supported by the on-screen-drawing examples: -

3.5.3.1 Getting Started

Let's presume the user knows nothing about AutoCAD - where do you begin? Well within this first tutorial we thought it would be useful to teach some of the basics such as the menu systems, opening & saving files and of course the all important help facility!

As with all the tutorials, the user can quickly skip down this page to the point of interest by selecting from the Contents list. Also, at the end of each tutorial page exercises are included relating to the topics covered, which tie in with those in the AutoCAD Assistant.

- **Entering Commands in AutoCAD**
- **File Management**
- **The Help facility**

- **Entering Commands in AutoCAD**

AutoCAD commands can be invoked by a variety of methods including: -

Typing the command name.

Selecting from the pull-down or side menus.

Selecting from the tool bar or box.

The way in which commands are set out in the standard AutoCAD menus will depend on the version you are using. It is also possible to customise the menus to suit yourself or a particular application - for details see the AutoCAD Manuals.

The Command prompt sits at the bottom left-hand side of the AutoCAD screen and it is here that typed text, values or AutoCAD drawing commands are recorded. Likewise the Command prompt indicates the status of the current command in operation. Most of the commands covered by these tutorials are described from the point of view of entering them at the Command: prompt. Ultimately it is up to you to decide on your preferred method of entry.

- **File Management**

The procedure used to create, open and save files with AutoCAD is very similar to that of other Windows-based software.

Creating a New Drawing

The procedure for creating a new drawing is as follows: -

From the FILE menu select NEW, or type NEW at the Command: prompt.

A dialogue box will then appear in which you can type a name for the drawing and choose whether or not to use a prototype drawing.

The prototype governs various default settings when you first start a drawing, including limits, grid spacing and text font. The default setting is to use the standard ACAD prototype - for more details refer to the AutoCAD manual).

Click on OK to confirm your choices and begin the drawing.

Saving the Current Drawing

When saved, drawings in AutoCAD are automatically given a .DWG extension. On subsequent saves to the first, AutoCAD will create a backup file (.BAK extension) of the previous saved version.

The number of characters you may use in a filename is either 8 (for Windows 3.1 etc.) or 24 (for Windows 95). Try not to use symbols in the filename as certain ones are not allowed (- and _ are OK).

The options for saving your drawings to file are as follows: -

SAVE

Saves the drawing after requesting a filename (and directory location).

SAVEAS

Works in the same way as SAVE but will always prompt for a filename - useful for creating copies of your drawings.

QSAVE

Saves the drawing using the current filename or, if no name has previously been defined, will prompt you to enter a name.

Opening an Existing Drawing

Use the OPEN command to retrieve a previously saved drawing. From the dialogue box which appears you must specify (or select) the location of the file and the filename.

- **The Help Facility**

AutoCAD offers an extensive on-line help facility describing the make-up and operation of most of its commands. After entering the HELP command, the use of Help in AutoCAD is the same as for other Windows based software. The main features are briefly described below.

Contents

Accesses the main contents page for the help file.

Search

Select to perform a keyword search of the topics and commands covered by the help file.

Bookmark

Bookmarks can be added to frequently accessed pages of the help file, so that they may be instantly recalled whenever required.

EXERCISE

Experiment with different ways of accessing the AutoCAD Help facility. Investigate the use of Help by searching for help on opening and saving files.

3.5.3.2 Co-ordinate Geometry

In this tutorial we will discuss AutoCAD's Co-ordinate Geometry Formats, drawing Limits, the use of the LINE command and some other useful basic commands. For your convenience at later reference, selecting one of the titles below will instantly access the relevant point in the exercise. This format is used in many of the tutorials.

- **Co-ordinate Geometry Formats**
- **Drawing Limits**
- **LINE Command**
- **Useful Basic Commands**

- **Co-ordinate Geometry Formats**

Absolute Cartesian: x,y

Relative Cartesian: @x,y

Relative Polar: @length<angle

AutoCAD, like many other CAD packages, allows the user to draw accurately. This is achieved by making use of the following Co-ordinate Geometry Formats: -

Absolute Cartesian: x,y

Whereby x and y are values that are keyed in with reference to the point 0,0. e.g. 40,60 represents a position 40 positive units in the x direction and 60 positive units in the y direction.

Relative Cartesian: @x,y

Whereby x and y are values that are keyed in relative to the last point. e.g. @20,-30 represents a position 20 positive units in the x direction and 30 negative units in the y direction, relative to the last point.

Relative Polar: @length<angle

Whereby a value in length is given followed by an angle relative to the last point. e.g. @56<45 represents a position 56 units at an angle of 45 degrees relative to the last point.

The above methods of location can be utilised with a variety of AutoCAD commands such as LINE, ARC and COPY.

- **Drawing Limits**

When creating 2D drawings with AutoCAD it is usual practice to begin by defining the Limits of the drawing. An AutoCAD drawing's limits define its boundaries, in a similar way to how an 'A' size piece of paper defines the area of a traditional engineering drawing. However with AutoCAD there is no limit to the size of 'paper' you can use. This means that you can always draw at full size (1:1 scale) which has several advantages including accuracy, construction time and the ability to use the geometric data in other CAD/CAM applications.

Note: When you produce hardcopy (prints or plots) of your drawings, the apparent scale factor will be dependent on the size of paper used and choices made in the printing options.

When deciding on the limits for your drawing it is generally best to set much larger values that you initially need. You can always zoom in (covered in the Drawing Aids tutorials) to the area you are currently working in and in any case it is possible to change the limits at any time.

Use of the LIMITS command as seen from the command prompt within AutoCAD (you should type the text shown in bold): -

Command: **LIMITS**
ON/OFF/[Lower left corner][current value]:

OPTIONS
ON

When the limits are switched ON, AutoCAD will not allow you to enter points outside of the drawing limits.

OPTIONS
OFF

When turned OFF, you may enter points outside the drawing limits.

Entering a Point.

If you enter a co-ordinate point (as discussed above), this will be used as the lower left-hand corner of the limits (the default is 0,0). You will then also be prompted to enter a point for the upper right-hand corner to govern the overall drawing limits.

Example of a drawing area with Limits set to 297x210 units (equivalent to an A4 sheet of paper)

- **LINE Command**

The LINE command lets you draw straight lines. You can specify the desired endpoints using either 2D or 3D co-ordinates, or a combination of the two. If you enter 2D co-ordinates, AutoCAD uses the current elevation as the Z component of the point. The format in which co-ordinates should be entered is as described in the Co-ordinate Geometry Formats section above.

Use of command as seen from the command prompt (you should type the text shown in bold): -

Command: **LINE**
From point: Enter a point
To point: Enter a point
To point: Enter a point, etc. until end of line sequence.

Options that may be used with the LINE command area as follows: -

To erase the last line segment without exiting the LINE command, enter u (undo) at the To point: prompt.

You can continue drawing from the last Line or Arc constructed by responding to the From point: prompt by hitting the space or return keys.

If you are drawing a sequence of lines that will become a closed polygon, you can reply to the To point: prompt with c (close) to draw the last segment and close the polygon.

You can constrain lines to horizontal or vertical by using the ORTHO command (covered in the Drawing Aids tutorial).

- **Useful Basic Commands**

UNDO

If you make a mistake at any point, the UNDO command can be used to back up a step. UNDO can be used repeatedly for the work you have undertaken in a current session (i.e. since opening the drawing) and may also be used within commands, for instance to erase the last part of a continuous line.

REDO

The REDO command has the opposite effect to UNDO with the same restrictions of use applying.

ESCAPE / CTRL+C

Pressing the ESCAPE [Esc] key (ACAD13/14) or CTRL and C buttons simultaneously (ACAD12 and below) will instantly cancel any command you are currently performing.

EXERCISE

In the AutoCAD Assistant, under Activities select Co-ordinate geometry and follow the on-screen instructions to complete the first exercise.

3.5.3.3 Script Files

The AutoCAD SCRIPT command provides the facility by which sequences of commonly used commands may be chained together and invoked from within the drawing editor. The file containing the commands must be of the ASCII format and the filename must have the extension SCR.

Packages such as Windows 'WRITE' or 'WORD' can be used to compile the script file but when saving, the option "Save As" must be used and the type "Text" selected for a TXT extension. The TXT extension must then be changed to SCR to enable AutoCAD to read the file. Remember that the file content must satisfy all the normal AutoCAD responses.

The SCRIPT command causes commands to be read from the specified script file.

Use of the SCRIPT command as seen from the AutoCAD command prompt (you should type the text shown in bold): -

Command: **SCRIPT**
Script file [default]: Enter the script filename.

AutoCAD reads commands from the script file, until one of the following events occurs: -

It reaches the end of the file.

You enter a character -- preferably -- from the keyboard.

A command error occurs.

Note: If the script is terminated early due to a command error or by keyboard entry, it can be resumed using the RESUME command.

The RSCRIPT command can be inserted in the script file to restart the script from the beginning.

EXERCISES

Exercise 1.

Create and run an AutoCAD script file based on the Command List shown below. This exercise can also be found in the AutoCAD Assistant, under the Script Files activity.

Exercise 2.

Develop a script file to reproduce the WW2.DWG drawing created in the last tutorial.

Exercise 3.

Develop two script files to set up A4 Horizontal and Vertical drawing sheets including borders and Name/Title blocks.

Script for Exercise 1: -

Note: The spaces in-between each set of co-ordinates are intentional (they represent strikes of the return key) and must be left in when you type the script - note their effect when the script is run.

```
limits
0,0
297,210
zoom
all
line
40,50
90,50
90,100
40,100
```

```
40,50

line
110,50
@50,0
@0,50
@-50,0
@0,-50

line
180,50
@50<0
@50<90
@50<180
@50<-90

line
60,120
@60,0
@-30,51.96
@-30,-51.96


150,120
@60<0
@60<120
@60<240
```

3.5.3.4 Drawing Aids

AutoCAD helps the user to draw accurately through the use of the following tools: -

- **GRID and SNAP**
- **PAN and ZOOM**
- **ORTHO mode**
- **POINT**

- **GRID and SNAP**

SNAP and GRID are two partner tools that can be used to assist in geometry creation. Both commands can work independently of each other and are variable. It would therefore be possible to have a grid of 10 whilst snapping to 7. However, it is recommended that settings that are multiples of each other are used for convenience, such as a grid of 10 with a snap of 5. This often prevents the screen being clogged with grid locations whilst still allowing intermediate locations to be selected.

Note: The co-ordinate display box is very useful for providing an indication of line lengths and angles when drawing solely using grid and snap.

An example of an AutoCAD grid was shown under 'Limits' in the Co-ordinate Geometry section of these tutorials.

The GRID command controls the display of a grid of alignment dots to help you place objects in drawings.

Use of GRID command as seen from the AutoCAD command prompt (you should type the text shown in bold): -

Command: **GRID**
Grid spacing(X) or ON/OFF/Snap/Aspect
[current]:

OPTIONS
Spacing
(X)

A simple number sets grid spacing in drawing units. A number followed by "X" (e.g., "2X") sets the grid spacing to a multiple of the current snap resolution. A value of zero locks the grid spacing to the current snap resolution.

OPTIONS
ON

Turns grid on with previous spacing.

OPTIONS
OFF

Turns grid off.

Snap

Locks the grid spacing to the current snap resolution (same as a spacing value of zero)

Aspect
Permits a grid with different horizontal and vertical spacing.

Note: You can also turn GRID on and off using the F7 key or CTRL+G.

Snap

The SNAP command lets you control the snap resolution, the spacing of an imaginary grid of dots with which newly designated points must align. You can alter the resolution or turn it off entirely for freestyle drawing.

Command: **SNAP**
Snap spacing or
ON/OFF/Aspect/Rotate/Style [current]:

OPTIONS
Snap Spacing
Sets alignment spacing.
ON
Aligns designated points.
OFF
Does not align designated points.
Aspect
Sets different X/Y snap resolution.
Rotate
Rotates snap grid by specified angle and sets a specified base point for the grid.
Style
Sets Snap style to either Isometric or Standard.

Note: Snap can be turned on and off with the F9 key or CTRL+B.

- **PAN and ZOOM**

The PAN and ZOOM commands allow you to control the view of your drawing on the graphics display. Both PAN and ZOOM can be used as nested commands (in most situations) which means you can use them while another command is running (but not by typing at the Command: prompt, you must select PAN or ZOOM from one of the menus in these situations). For instance you may want to move the screen using PAN to follow a line you are halfway through constructing.

The PAN command enables the re-positioning of a drawing on the screen. The drawing itself does not move, only the view of the drawing. Imagine looking down through a camera onto the drawing sheet, PAN moves the camera around to alter the viewing position.

The command requires the specification of a vector along which to move the view of the drawing. This vector is defined by either entering a displacement from the current position or selecting two points to indicate either end of the line of movement. You can either specify points using the usual AutoCAD co-ordinate format or by simply clicking on the screen.

Command: **PAN**
Displacement: either enter displacement or first point on movement vector
Second point: either just hit return (for the displacement option) or enter second point on movement vector.

To use the camera analogy again, the ZOOM command works in the same way as a camera's zoom lens. Hence you zoom in to a drawing to work on more detailed areas, or zoom out to look at the overall picture.

Command: **ZOOM**
All/Center/Dynamic/Extents/Left/Previous/Vmax/Window/:

OPTIONS

All

Creates view of entire drawing area (as specified by the drawing limits) on screen.

Center

Zooms around a user specified center-point with given magnification.

Dynamic

Creates a scaled view interactively using a view box generated over the drawing.

Extents

Zooms to fit the whole drawing (not the drawing area as with Zoom All) to the graphics area.

Left
Works in the same way as Zoom Center but using a point specified as being at t he left of the zoom area.

Previous
Restores the last Zoom view used.

Vmax
Zooms out as far as possible to the virtual screen.

Window
Zooms in to an area defined by picking two opposite corners of a rectangle in the current view.

Scale
Zooms around the current center of the screen by a specified scale factor, e.g. a factor of 2 would double the magnification whilst 0.5 would halve it.

- **ORTHO Mode**

The ORTHO command lets you control orthogonal drawing mode. When orthogonal mode is set to ON, movement within the drawing is constrained to the vertical and horizontal axes, in steps defined by the current Grid and Snap settings.

Command: **ORTHO**
OFF/ON :

OPTIONS
ON
Turns orthogonal mode on.
OFF
Turns orthogonal mode off.

Note: When the SNAP Grid is rotated, ORTHO mode rotates accordingly. Also, if the isometric snap style is in effect, ORTHO mode is applied to the axis pair associated with the current isometric plane. ORTHO can be turned on and off with the F8 key or CTRL+O (depending on your system's settings).

- **POINT**

AutoCAD has the facility to enter points onto a drawing. Various styles and sizes of points can be added which will remain as part of the finished drawing or which can be used in order to facilitate the construction of the drawing. This might include the addition of points to identify areas of interest, such as datum points or origin locations. Points used in this manner are easily erased prior to saving or plotting the drawing.

Geometry can be locked onto points by using the object snap NODE locator and the exact positions of the points can be determined by using the ID command (as can any geometric locations).

EXERCISES

Exercise 1.

Investigate the AutoCAD Help facility on POINT and record the key issues. Use this information to experiment with the POINT command. Record a range of point styles and their codes.

Exercise 2.

Familiarise yourself with the use of the GRID, SNAP and ORTHO commands by attempting the drawings found under the Drawing Aids activities in the AutoCAD Assistant. Some of these drawings require the use of commands you have not yet covered i.e. FILLET, CHAMFER and ARC. See how you get on, if you have difficulty leave the relevant features off the drawings and add them later.

Exercise 3.

Using the drawings you have created, experiment with the various options for PAN and ZOOM.

3.5.3.5 Editing Techniques

So far we have looked at commands used for constructing geometry. In this tutorial you will learn how to remove all, or parts of, the lines you have created. The following commands are covered: -

- **ERASE**
- **BREAK**
- **TRIM**

- **ERASE**

Everyone makes mistakes and when you are using CAD you tend to make a lot of them! To quickly get rid of any unwanted geometry simply use the ERASE command, select the unwanted items and hit the return key.

When using commands like ERASE, MOVE and COPY, in order to decrease drawing time you will often want to select several items at once. When the facility to select more than one item at a time is available AutoCAD issues a Select objects: prompt and replaces the crosshairs of the graphics cursor with a small box. You can automatically use the cursor to pick objects individually or to draw a selection window around them. You can also use keywords and the cursor to select objects in a variety of ways.

SELECTION OPTIONS

Point

    One object selected.

Multiple

    Multiple objects selected by pointing.

Last

    Last object.

Previous

    All objects in previous selection set.

Window

    Objects within window.

Crossing

    Objects within or crossing window.

Box

Automatic Crossing (to the left) or window (to the right).

Auto

Automatic BOX (if pick in empty area) or single object pick.

Single

One selection (any type).

Add

Add mode: adds following objects to selection set.

Remove

Remove mode: removes objects from selection set.

Undo

Undoes / removes last item selected in set.

- **BREAK**

The BREAK command deletes part of a Line, Trace, Circle, Arc, or 2D Polyline, or splits the object into two objects of the same type.

Command: **BREAK**
Select object:
Enter first point:
Enter second point:

If you break a circle it changes to an arc by deleting the portion from the first point to the second, going counter-clockwise. Breaking a 2D Polyline with non zero width will cause the ends to be cut square. If you select the object by pointing to it, the break is assumed to begin at the selection point. AutoCAD then prompts:

Enter second point (or F for first point):

If you want to begin the break at a point where another object intersects with the object to be broken, choose an unambiguous point to select the object and then enter F in response to the prompt. You can then select the beginning and ending points of the break. If you want to split the object in two without deleting anything, enter the same point for both the first and second points of the break, by entering @ (last point) for the second point.

- **TRIM**

The TRIM command lets you trim objects in a drawing so they end precisely at a 'cutting edge' defined by one or more other objects in the drawing.

Command: **TRIM**
Select cutting edge(s)...
Select objects:

Lines, Arcs, Circles, and 2D Polylines (centerline of wide Polylines) can serve as boundary objects. All the selected edges are highlighted and will remain highlighted for the rest of the TRIM command. Once you've selected the boundary object(s) AutoCAD prompts:

<Select object to trim>/Undo:

Pick objects to trim by pointing to the part of the object to be trimmed. Respond with U to undo the most recent change, back to the first change made during the current TRIM command. Respond with [return] to end the command. If the selected point is between two intersections, the entity is deleted between the two intersection points. 2D Polylines are trimmed at their centerline.

EXERCISES

Exercise 1.

From the Editing Commands section in the AutoCAD Assistant, attempt the ERASE exercise.

Exercise 2.

Now move on to the TRIM and BREAK exercise.

3.5.3.6 Geometric Attachments

So far we have only looked at the construction of straight lines. AutoCAD has a variety of commands for the creation of more complex geometry. In this tutorial we shall be looking at some of these commands.

- **Circles**
- **Arcs**
- **Object Snap Modes**

- **Circles**

AutoCAD offers several options to enable you to construct circles under a variety of conditions, these are as follows:-

Center, Radius
Draws a circle based on center point and radius.
Center, Diameter
Draws a circle based on center point and diameter.
2 Point
Draws a circle based on 2 endpoints of diameter.
3 Point
Draws a circle based on 3 points on the circumference.
Tangent, Tangent, Rad
Draws a circle based on the radius and two lines the circle is tangent to.

- **Arcs**

As for circles, there is a range of different options for generating arcs.

3 Point
Arc based on 3 points.
Start, Center, End
Arc based on a start, center, and endpoint.
Start, Center, Angle
Arc based on a start point, center point, spanning an angle.
Start, Center, Length
Arc based on a start point, center point, and length of chord.
Start, End, Angle
Arc based on start point, endpoint, and specified angle.
Start, End, Radius
Arc based on a start point, endpoint, and radius.

Start, End, Direction
Arc based on a start point, endpoint, and direction from start point.
Center, Start, End
Arc based on a start point, center point, and endpoint.
Center, Start, Angle
Arc based on a center point, start point, and angle.
Center, Start, Length
Arc based on a center point, start point, and length of a chord.

- **Object Snap Modes**

When constructing any kind of geometry, 2D or 3D, it is extremely useful to be able to quickly locate standard points, such as the middle of a line or center of a circle. AutoCAD has a range of Object Snap Modes (similar to snapping to points on a grid) for doing this. When you become familiar with the use of these commands you will find them invaluable for helping you to construct geometry quickly and efficiently.

Object Snaps are used as nested functions, which means they operate within other commands such as LINE, ARC and CIRCLE. When you need to use an Object Snap Mode simply type it's name (or abbreviation, e.g. INT for Intersection) or select from the toolbox.

Options available with Object Snap: -

Center
Snaps to center of arc or circle.
Endpoint
Snaps to closest endpoint of arc or line: corner of Trace/Solid/3D Face.
Insert
Snaps to insertion point of Text/Block/Shape/Attribute.
Intersection
Snaps to intersection of line, arc, or circle.
Midpoint
Snaps to midpoint of arc or line.
Node
Snaps to node (point).
Perpendicular
Snaps perpendicular to arc, line, or circle.
Quadrant
Snaps to quadrant point of arc or circle.
Tangent

Snap to tangent of arc or circle.
Nearest
Snaps to nearest point of arc, circle, line, or point.

EXERCISES

To familiarise yourself with the commands discussed in this tutorial try the exercises in the Geometric Attachments section of the AutoCAD Assistant.

3.5.3.7 Additional Editing Commands

Here you will learn about the use of commands that help you to produce standard engineering features on your drawings.

- **FILLET**
- **CHAMFER**

- **FILLET**

The FILLET Command can be used to produce a fillet of specified radius between adjacent edges on a drawing.

Command: **FILLET**
Polyline/Radius/[Select first object]:
Enter P or R or Select two entities to fillet.

SELECTION OPTIONS
Polyline
Fillets an entire Polyline, or those segments to which the current radius can apply.
Radius
Sets the radius for subsequent fillets.
Trim
Select to choose whether or not to trim back the original geometry to the fillet.

Note: If you want to reset the radius before filleting, enter R and a value for the new radius. Then press [return] (to re-issue the FILLET command) and proceed to select the Polyline or two entities.

- **CHAMFER**

The CHAMFER command works in a similar way to FILLET to produce a chamfer between adjacent lines.

When producing a chamfer you may choose whether to specify two distance values (one for each edge of the chamfer) or a distance and angle (measured anti-clockwise from the first edge selected). These options enable you to specify any size of chamfer.

The Trim option toggles between whether or not to trim the original shape to the chamfer that is created.

Command: **CHAMFER**
Polyline/Distances/[Select first line]:

SELECTION OPTIONS
Polyline
    Chamfers an entire Polyline.
Distance
    Choose to specify a chamfer by two distances.
Angle
    Choose to specify a chamfer by one distance and an adjacent angle.
Trim
    To determine whether or not to trim back the original edges to the chamfer.
Method
    Alternative selection to choose between a Distance or Angle chamfer.

EXERCISES

To familiarise yourself with the FILLET and CHAMFER commands try the exercises in the Additional Editing Commands section of the AutoCAD Assistant.

3.5.3.8 Transformation Commands

Commands covered in this tutorial are as follows: -

- **MOVE and COPY**

- **MOVE and COPY**

The MOVE command is used to move one or more existing drawing entities from one location in the drawing to another.

COPY works in the same way as MOVE except that the original geometry is left in place, therefore creating a copy.

Command: **MOVE** or **COPY**
Select objects:

Base point or displacement: Select a point or enter a displacement vector.
Second point of displacement: Select a point.

Use any entity selection method to select the objects to move. Then enter an X,Y,Z displacement vector, or specify two points to indicate how far the objects are to be moved. If you designate a base point the selected object(s) are dynamically dragged to their new location. All forms of point entry are valid at the Base point or displacement: prompt. Entering a distance and angle moves the selected object(s) relative to the current UCS (user co-ordinate system) origin.

EXERCISES

To familiarise yourself with the commands covered in this section try the exercises in the Transformation Commands section of the AutoCAD Assistant.

3.5.3.9 Polylines

Commands covered in this tutorial are as follows:-

- **POLYLINES**
- **PEDIT**

- **POLYLINES**

The PLINE Command draws polylines, a connected sequence of lines and arc segments treated as a single entity.

You may either create open or closed polylines and although a PLINE may seem to form a closed shape, it will not truly be so unless the CLOSE command was used to create the final segment. As an alternative you may use the PEDIT > CLOSE command to achieve the same effect. Note that when filleting or chamfering closed-shape polylines, construction of the features will only be carried out on all corners of the polyline if it is properly closed.

Command: **PLINE**
From Point: Enter a Point

Arc/Close/Halfwidth/Length/Undo/Width/<endpoint of line>: Enter a point or select among options

Note: PLINE defaults to Line mode - drawing straight-line segments, unless you select the arc option to switch the command to arc mode.

SELECTION OPTIONS
Arc
    Create an arc segment on the polyline.
Close
    Create a closed polyline by adding a final segment back to the start point.
Halfwidth
    Enables a varying line thickness to be applied to segments of the polyline.
Length
    Create a straight segment on the polyline.
Undo
    Backup the last segment created.
Width
    Set width of the following polyline segments.

- **PEDIT**

The PEDIT command can either be used to alter an existing polyline or convert ordinary lines into polylines.

To convert a standard line into a PLINE, use PEDIT then select the line in question - you will then be prompted as to whether or not you want to convert the line into a polyline. If the requirement is to convert a series of consecutive lines into a polyline you should first convert one of the lines in the sequence then use the JOIN option under PEDIT to add the rest.

SELECTION OPTIONS

Close
: Convert an open pline to a closed pline.

Join
: Select to add segments to the polyline.

Width
: Change the width of a polyline.

Edit Vertex
: To move the connecting points (control points / vertices)between adjacent polyline segments.

Fit
: Creates a curve which passes through all the polyline vertices.

Spline
: Creates a best fit curve between polyline vertices.

Decurve
: Converts a Spline or Fitted pline back to straight segments.

Ltype Gen
: Toggles linetype along polyline.

Undo
: Backs-up last alteration to polyline.

Exit
: To exit from PEDIT.

EXERCISES

To familiarise yourself with the use of Polylines and Pedit try the exercises in the Polylines section of the AutoCAD Assistant.

3.6 Evaluation Of The Broadnet Project For Learning And Teaching 2D CAD

To evaluate the Broadnet Engineering CAD package a Questionnaire was designed and developed, the layout and format of which was set out to enable an Optical Mark Reader to be used for analysing the results. A copy of the final layout of the CAD evaluation questionnaire in its Optical Mark Reader format is included in Appendix III. Many questionnaires were studied which had been used for both multi-media and general use not associated to CAL regarding their design format, layout and method of entering the response to questions. Some were simple in their design and many others were complex requiring a significant amount of time to fill in the questionnaire with an infinite number of responses expected. However, good design features were noted and guidance was sought from an expert in the Planning, Statistics and Records Unit at the University of Wolverhampton in developing the Broadnet Engineering CAD Evaluation Questionnaire.

The general layout of the CAD evaluation questionnaire was designed for speedy completion by the respondent and focused on four main headings: -

- Learning Experience
- Using the package
- CAD Skills
- Performance

Under the four headings a series of questions were asked requiring one response by marking one of the five boxes per questions which were rated from Totally Agree 5, Agree 4, Neutral 3, Disagree 2 and Totally Disagree 1. The five box format was chosen for two main reasons: -

i) It gave the respondents a good range of selection by either agreeing or disagreeing with the questions asked and a middle option of neutral for those who felt they couldn't agree or disagree.

ii) The University of Wolverhampton was using a similar format for evaluating undergraduate awards and modules therefore it was proven and students were familiar with that format.

The following shows the four main headings and the associated questions of the CAD evaluation questionnaire: -

Learning Experience	**Totally Agree**	**Agree**	**Neutral**	**Disagree**	**Totally Disagree**
	5	**4**	**3**	**2**	**1**
The package allows me to work at my own pace when studying the module					
The package is relevant to my needs for learning CAD					
The package gives useful guidelines for using CAD					
The package gives me flexibility to study at anytime					
The package would encourage me to study alone more					
The package gives me control over my learning					

Using the package	**Totally Agree**	**Agree**	**Neutral**	**Disagree**	**Totally Disagree**
	5	**4**	**3**	**2**	**1**
The package is useful					
The instructions provided with the package make it easy to use					
The package is enjoyable					
The content material / activities contained in the package are too simple					
The package is interesting					
The package is motivating					

CAD Skills	Totally Agree	Agree	Neutral	Disagree	Totally Disagree
	5	4	3	2	1
The package introduces CAD in a logical manner					
The package will improve my 2D CAD skills					
The package could be used without any prior CAD knowledge					
I prefer using the package to Lecture and Tutorial instruction on CAD					

Performance	Totally Agree	Agree	Neutral	Disagree	Totally Disagree
	5	4	3	2	1
Performance of the computer was adequate					
Performance of the computer was too slow					
The computer monitor was adequate					
The computer monitor was too small					
The software ran with no problems					
I would have preferred the software downloaded from a floppy disc format					
I would have preferred the software in CD format					

During the development stage the questionnaire was tested on a small group of students (six) who were the target audience because their perceptions and understanding of the questions would be different to my own. This raised a number of points and ambiguities and consequently wording and questions were modified to rectify this. Originally a lot of the questions asked were repeated in the negative. This method is likely to produce redundant information and may serve to irritate respondents therefore these areas of repetition were cut out.

3.6.1 CAD Evaluation Questionnaire Results

The evaluation was carried out using twenty first-year undergraduate students from the BSc CAPD course who had worked through the package. All the students had IT skills acquired from previous modules but most had little CAD skills. The results were scanned into the Optical Mark Reader and passed into a spreadsheet package, reference (Table 3.6.1, Evaluation Data for Broadnet Engineering 2D CAD). The data was then transferred into 3D pie-chart format to provide responses to each question as a percentage format, reference (Chart 3.6.1 to 3.6.23 inclusive). Copies of these results are included in the following nine pages.

Evaluation Data for Broadnet Engineering 2D CAD	1 Totally	2 Disagree	3 Neutral	4 Agree	5 Totally
broadnet\eval2-files\data	Disagree				Agree
The package allows me to work at my own pace when studying the module	0	0	1	10	9
The package is relevant to my needs for learning CAD	1	0	4	13	2
The package gives useful guidelines for using CAD	1	0	4	14	1
The package gives me flexibility to study at anytime	1	0	2	9	8
The package would encourage me to study alone more	1	2	8	6	3
The package gives me control over my learning	0	2	6	7	5
The package is useful	0	2	2	9	7
The instructions provided with the package make it easy to use	0	1	5	11	3
The package is enjoyable	1	2	10	7	0
The content material / activities contained in the package are too simple	0	2	10	6	2
The package is interesting	0	2	10	8	0
The package is motivating	0	3	11	6	0
The package introduces CAD in a logical manner	0	1	4	15	0
The package will improve my 2D CAD skills	0	0	5	14	1
The package could be used without any prior CAD knowledge	1	4	10	4	1
I prefer using the package to Lecture and Tutorial instruction on CAD	3	7	8	2	0
Performance of the computer was adequate	0	3	8	8	1
Performance of computer was too slow	0	4	8	7	1
The computer monitor was adequate	2	5	10	3	0
The computer monitor was too small	0	3	6	5	6
The software ran with no problems	1	2	3	13	1
I would have preferred the software downloaded from a floppy disc format	2	5	8	4	1
I would have preferred the software in CD format	1	3	9	5	2

Table 3.6.1

Learning Experience

Chart 3.6.1 The package allows me to work at my own pace when studying the module

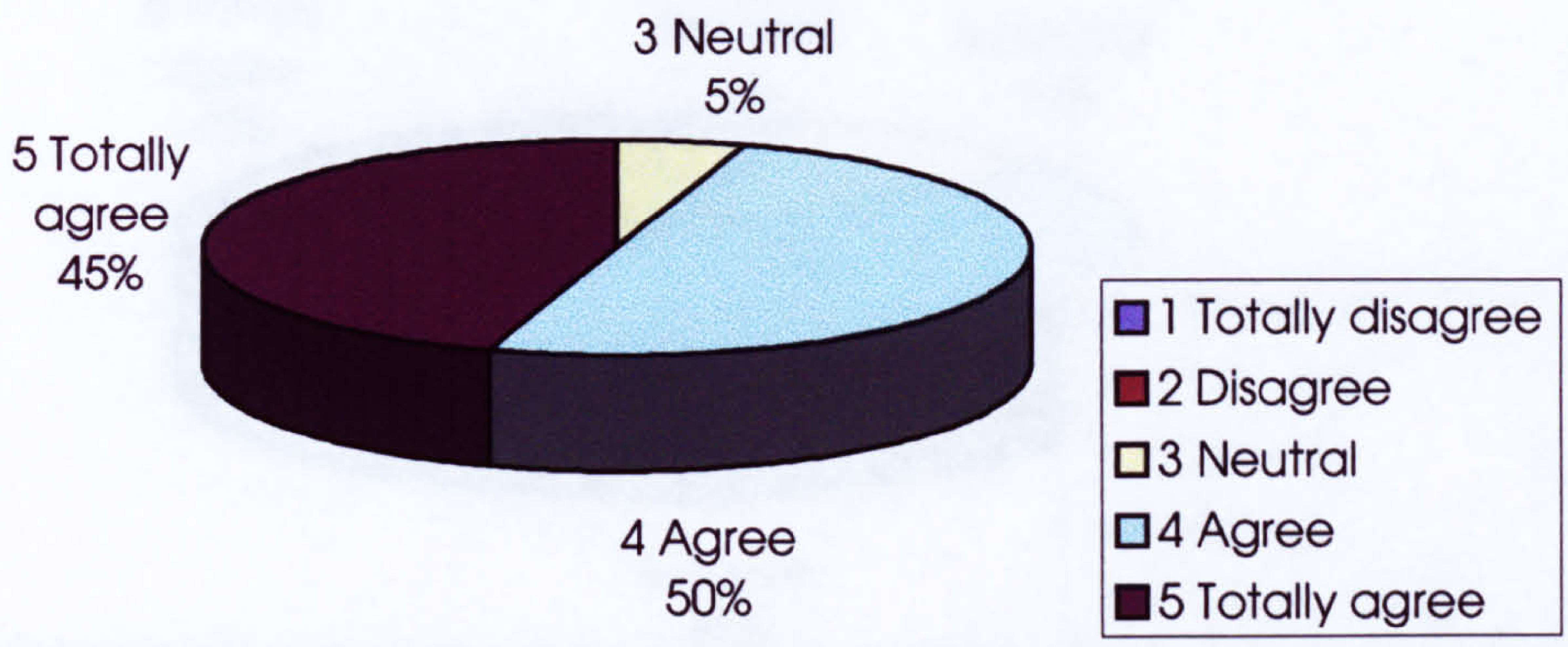


Chart 3.6.2 The package is relevant to my needs for learning CAD

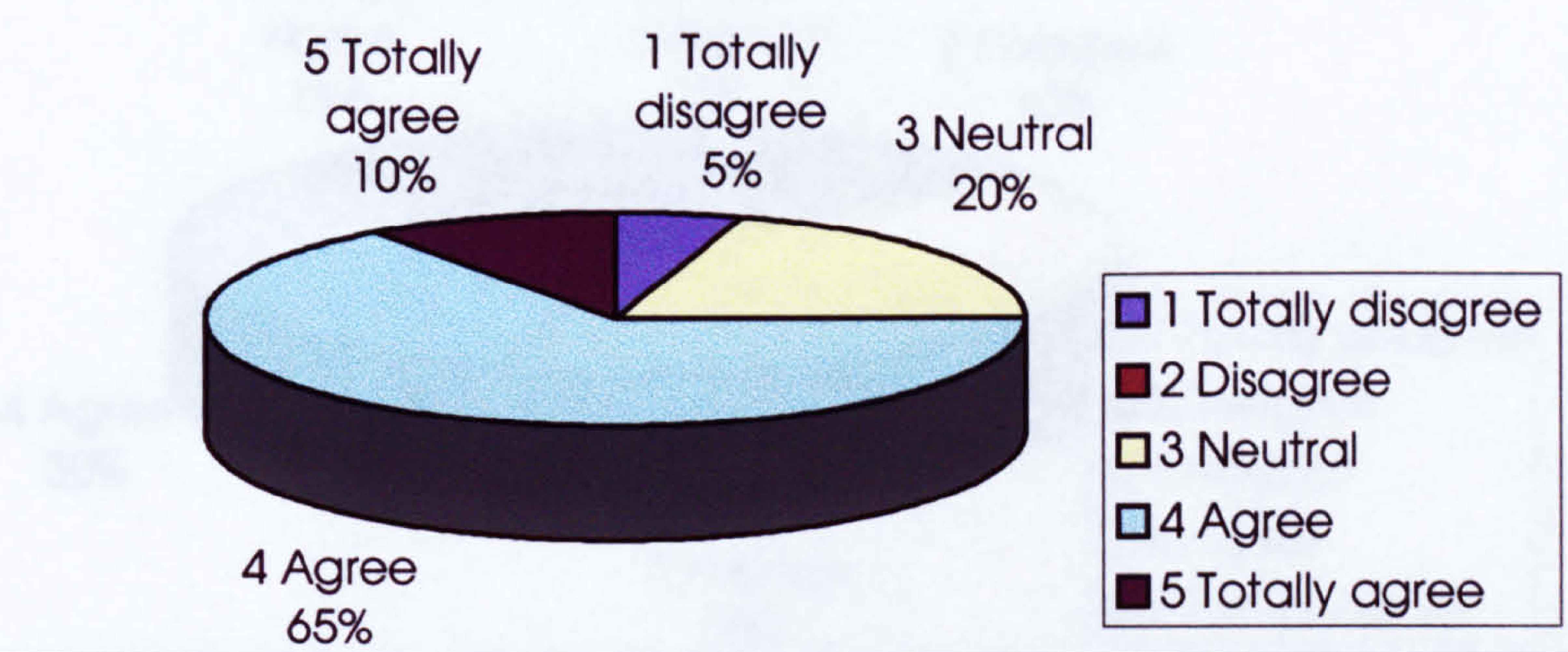
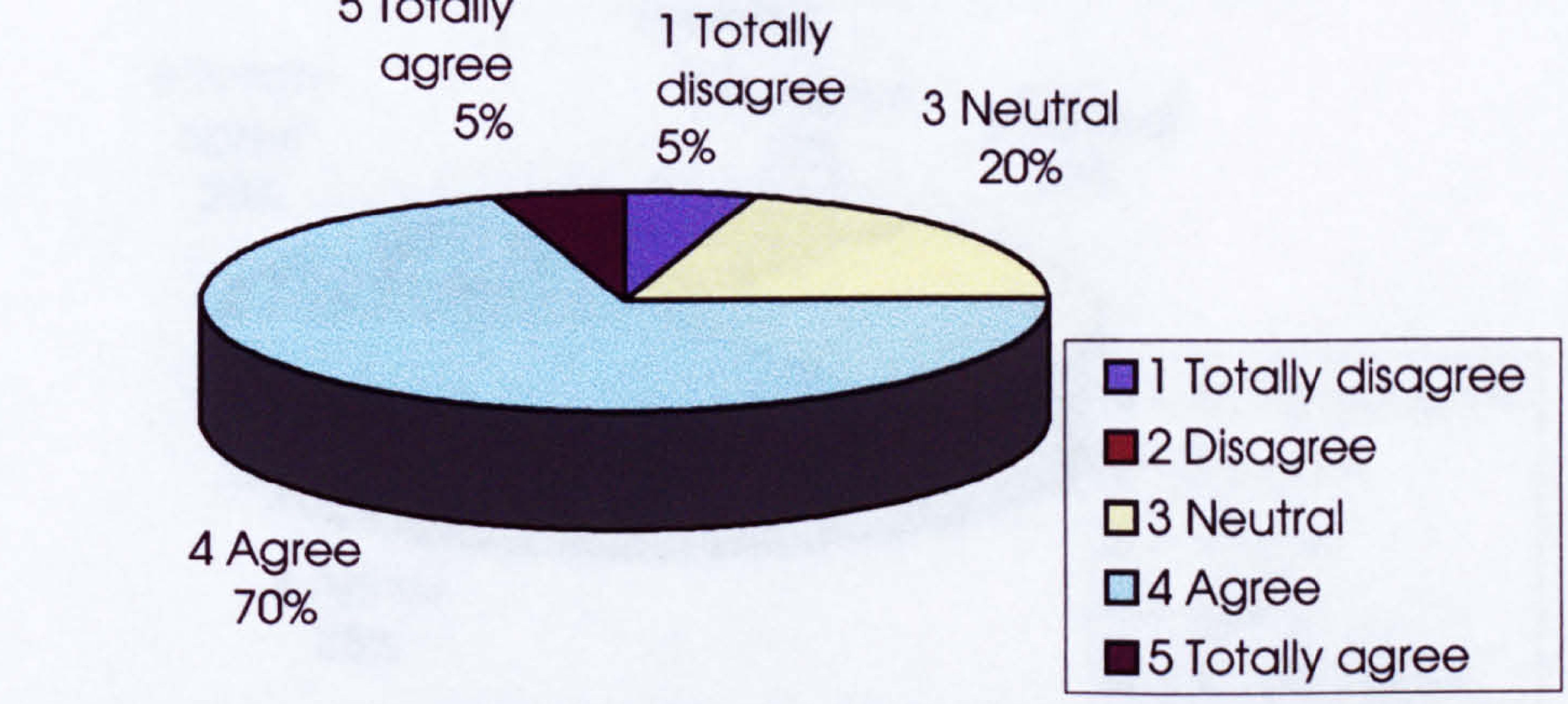


Chart 3.6.3 The package gives useful guidelines for using CAD



Learning Experience

Chart 3.6.4 The package gives me flexibility to study at anytime

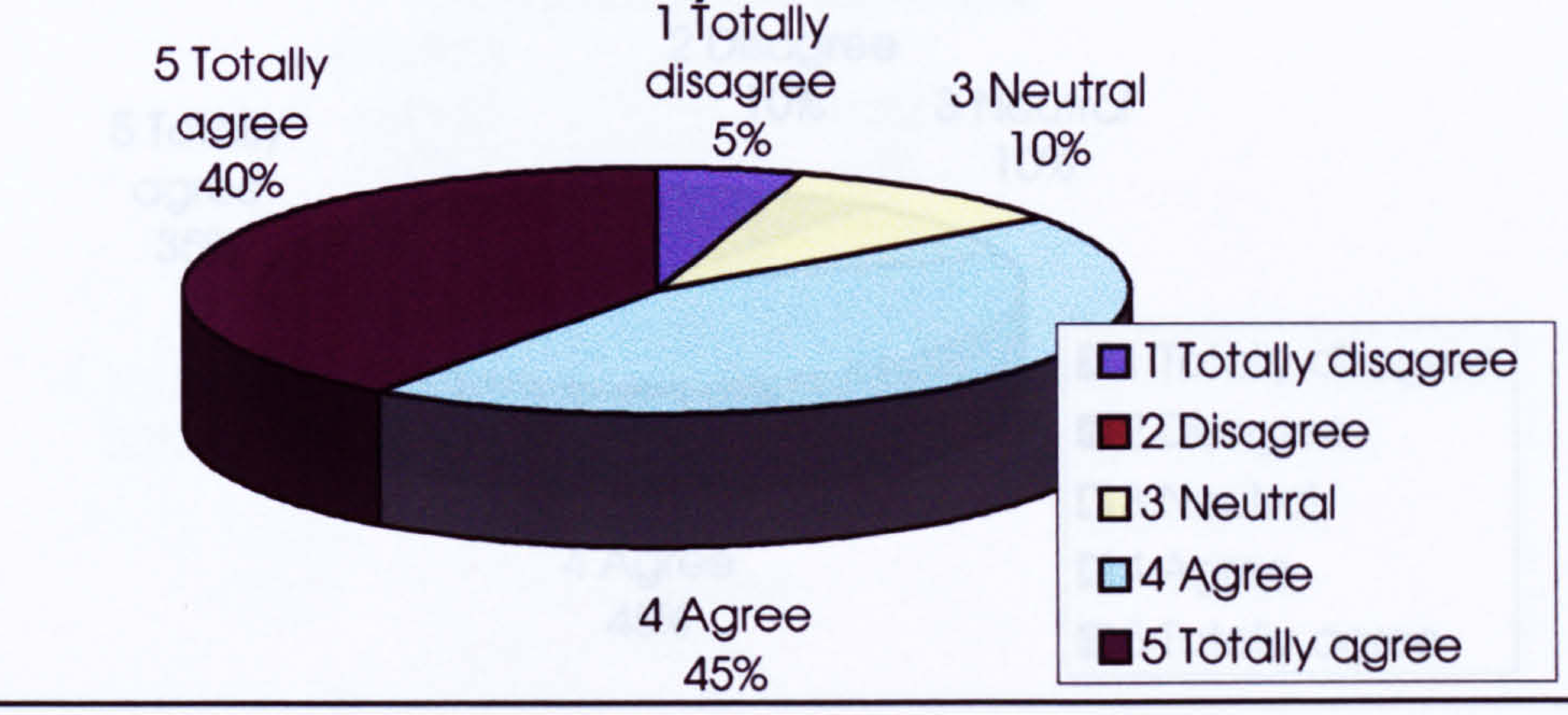


Chart 3.6.5 The package would encourage me to study alone more

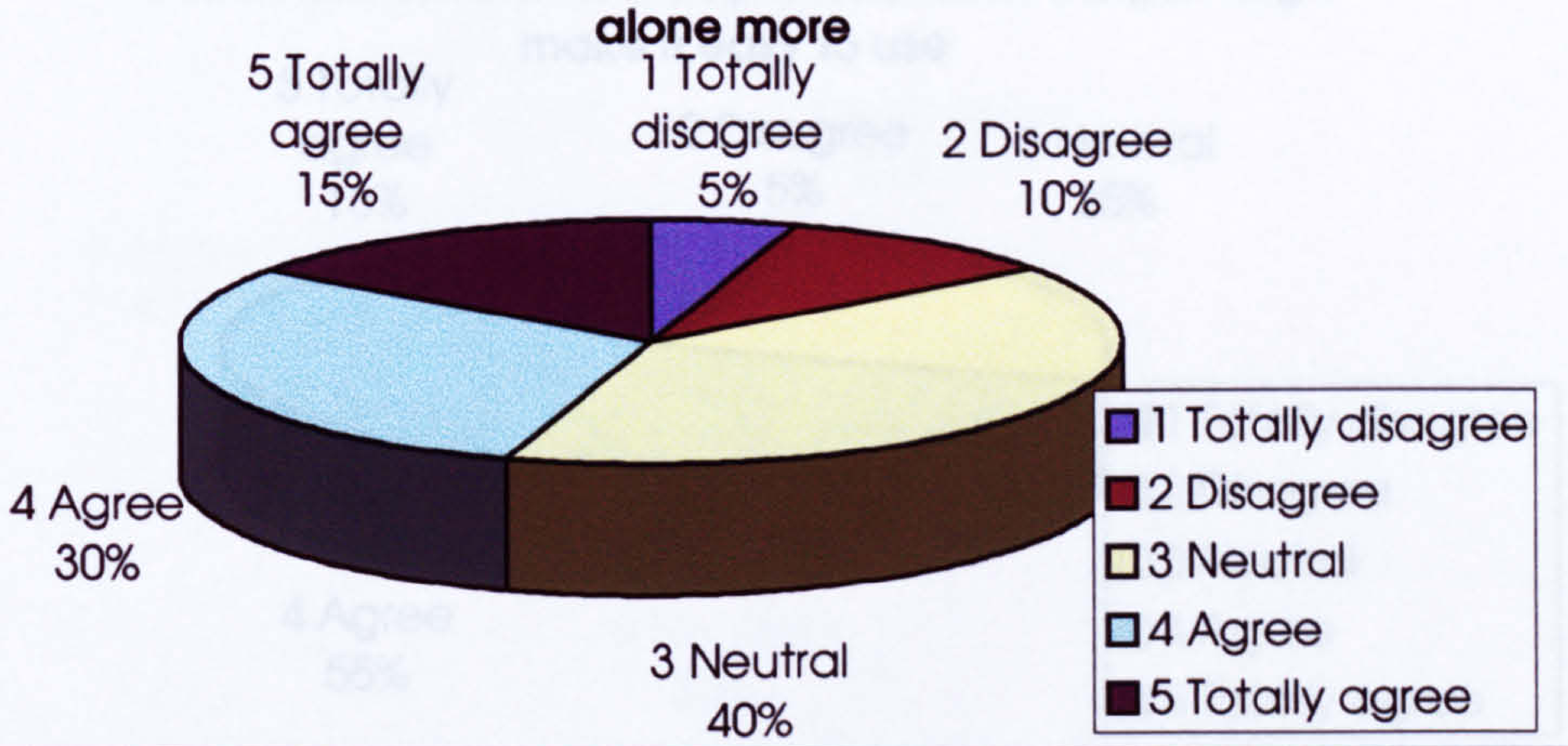
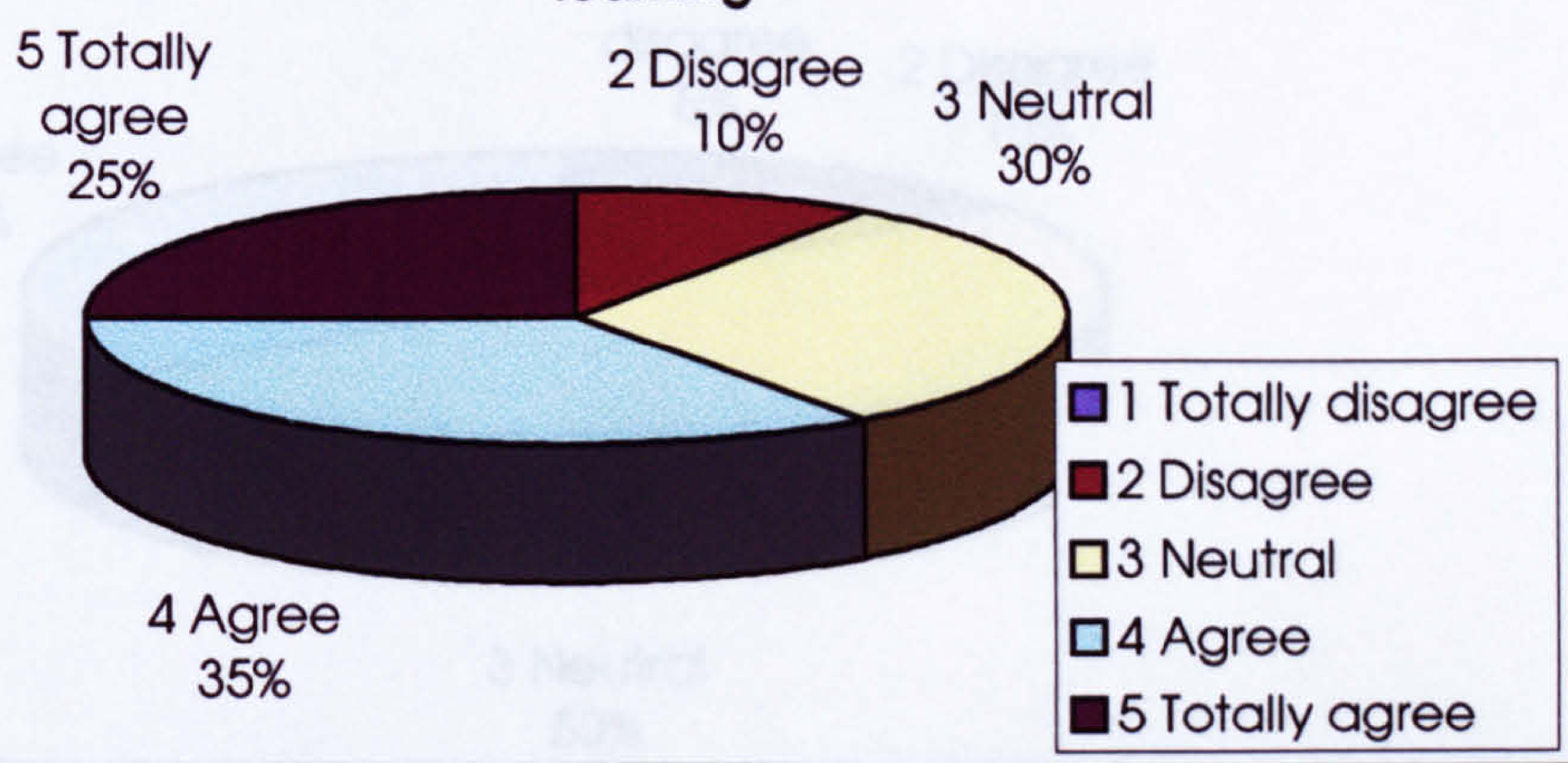
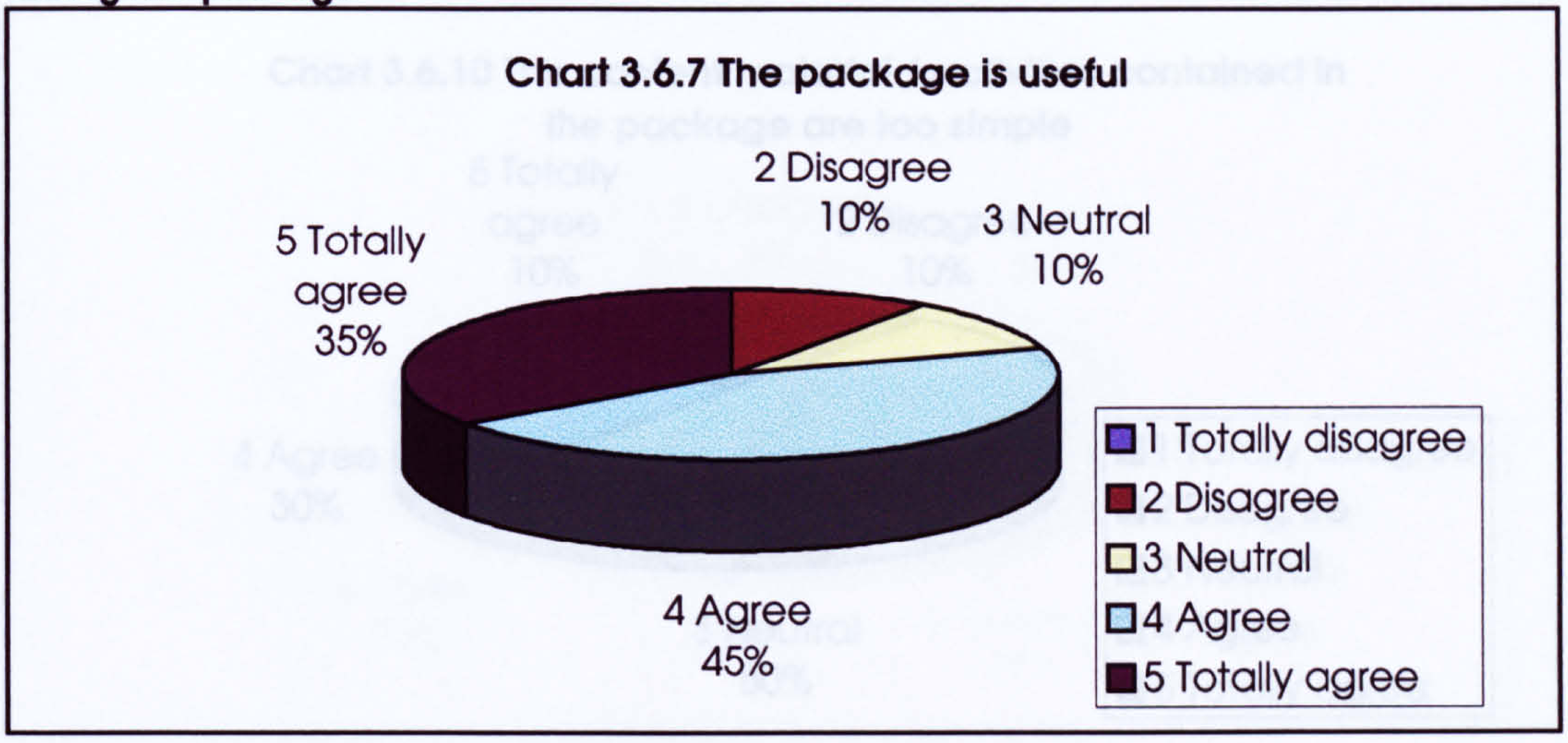
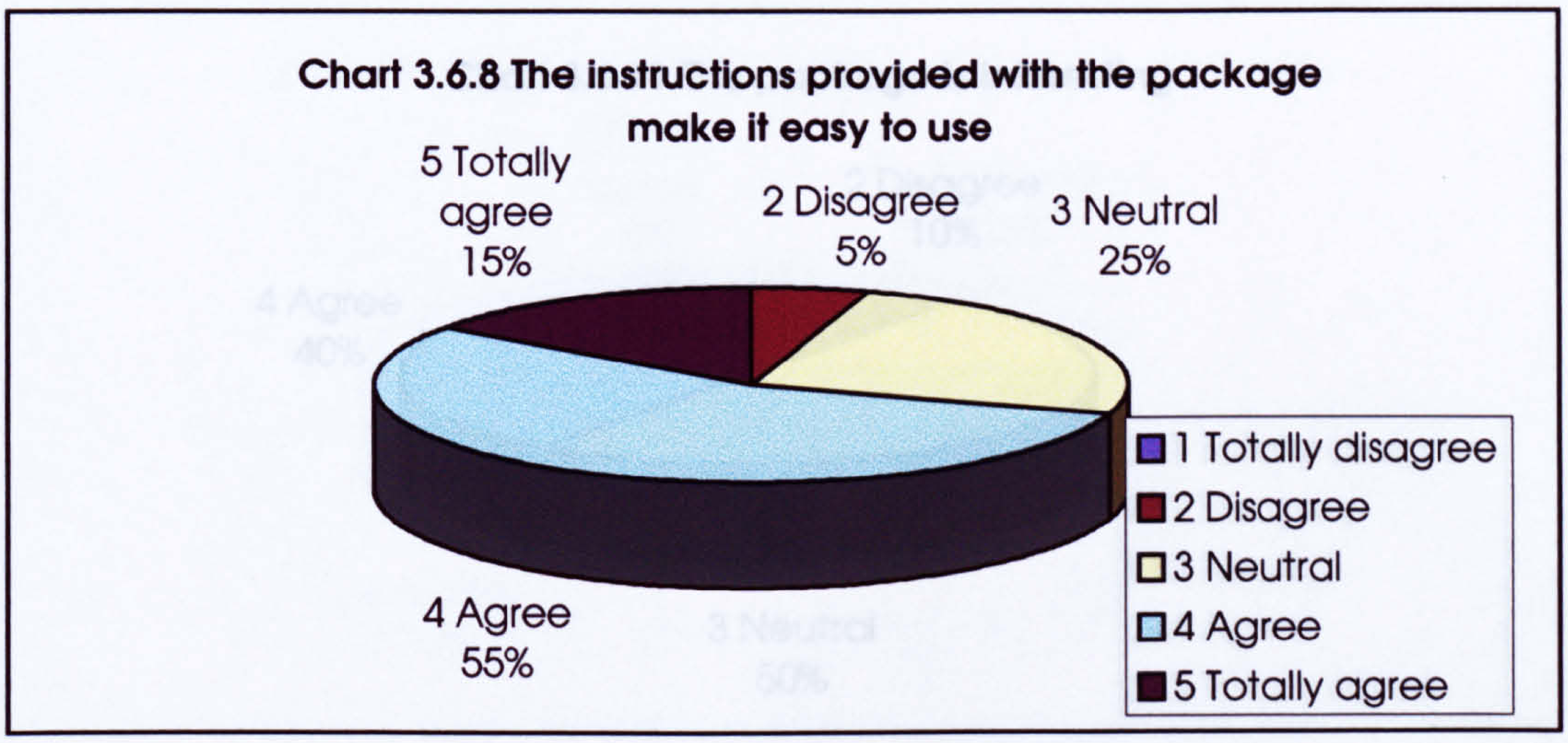


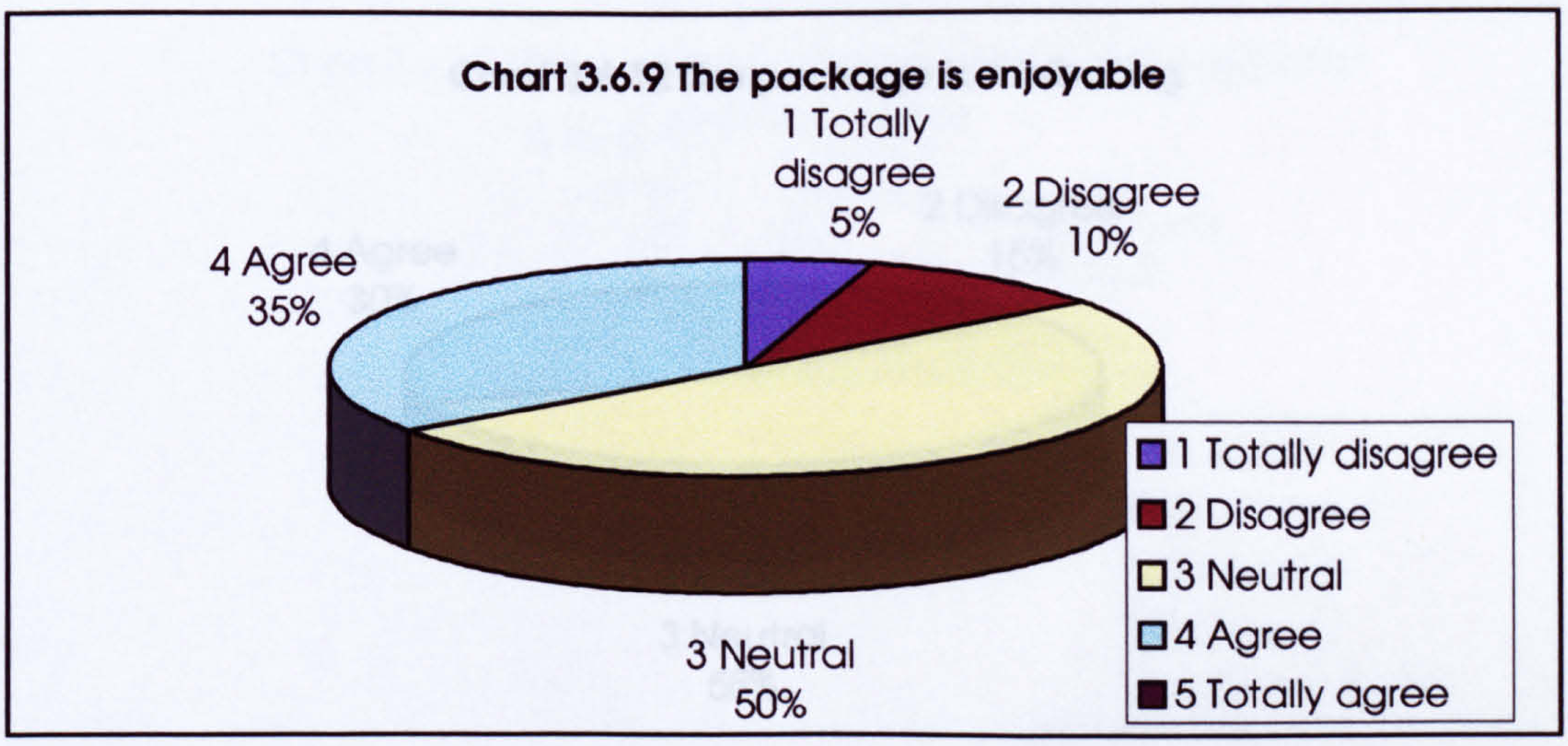
Chart 3.6.6 The package gives me control over my learning



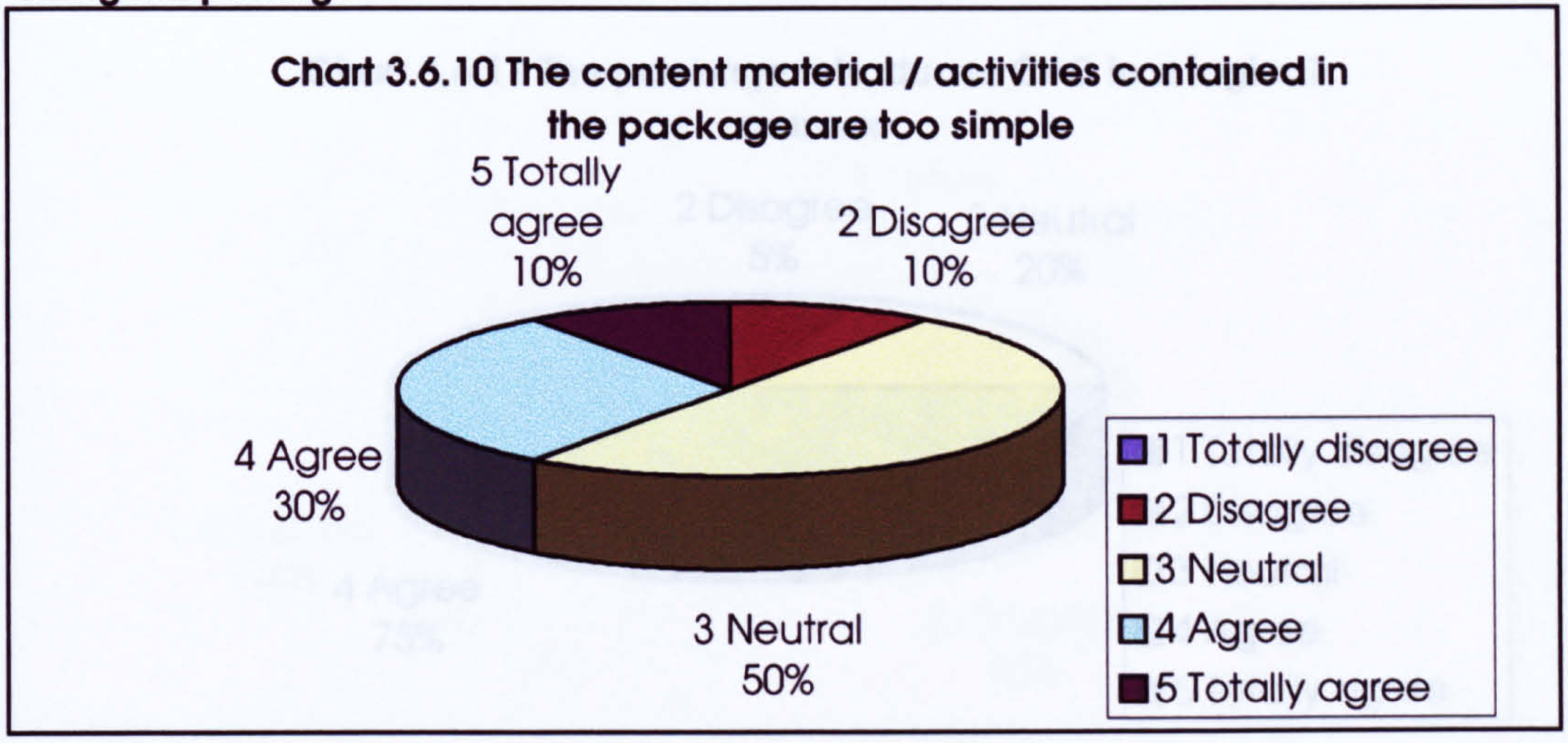
Using the package

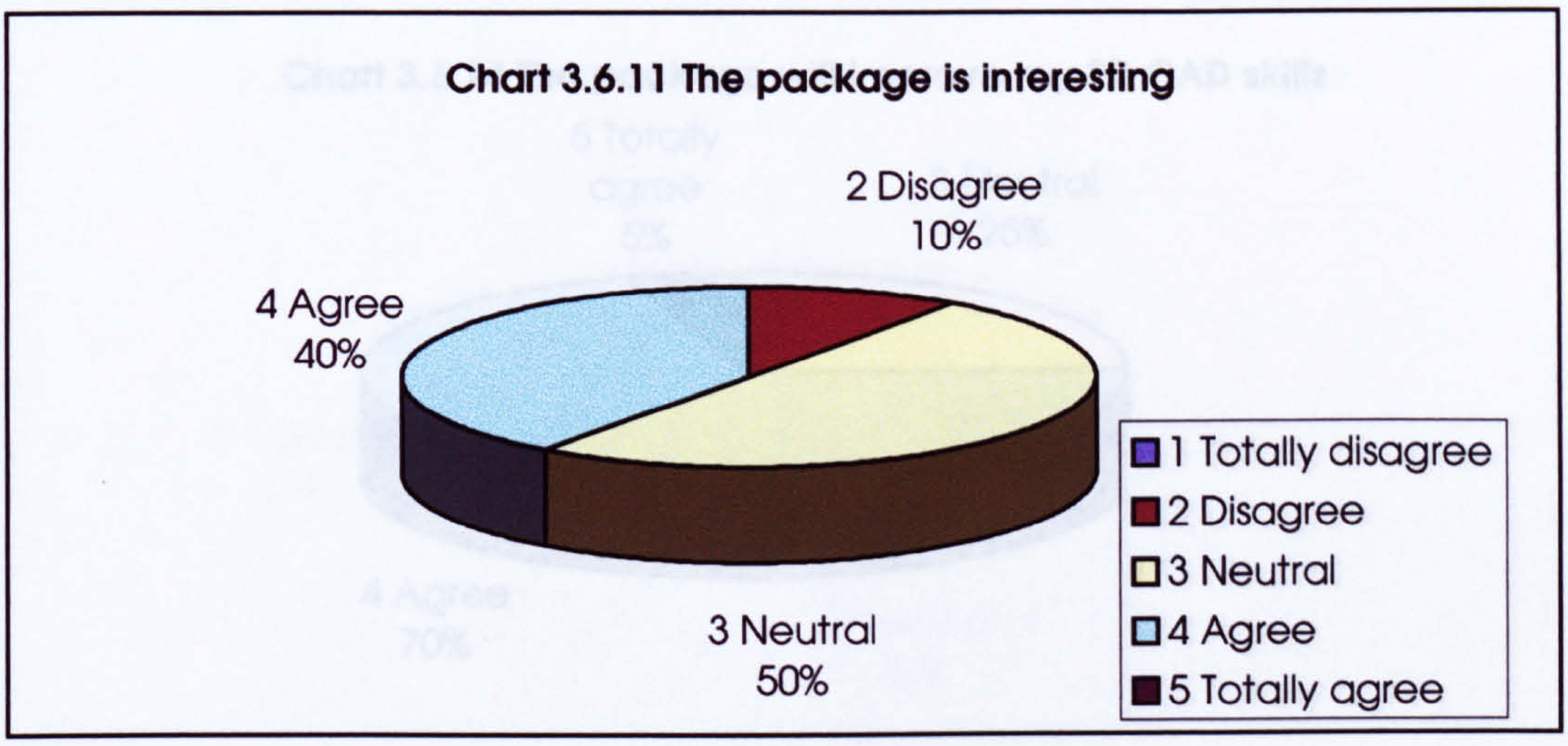


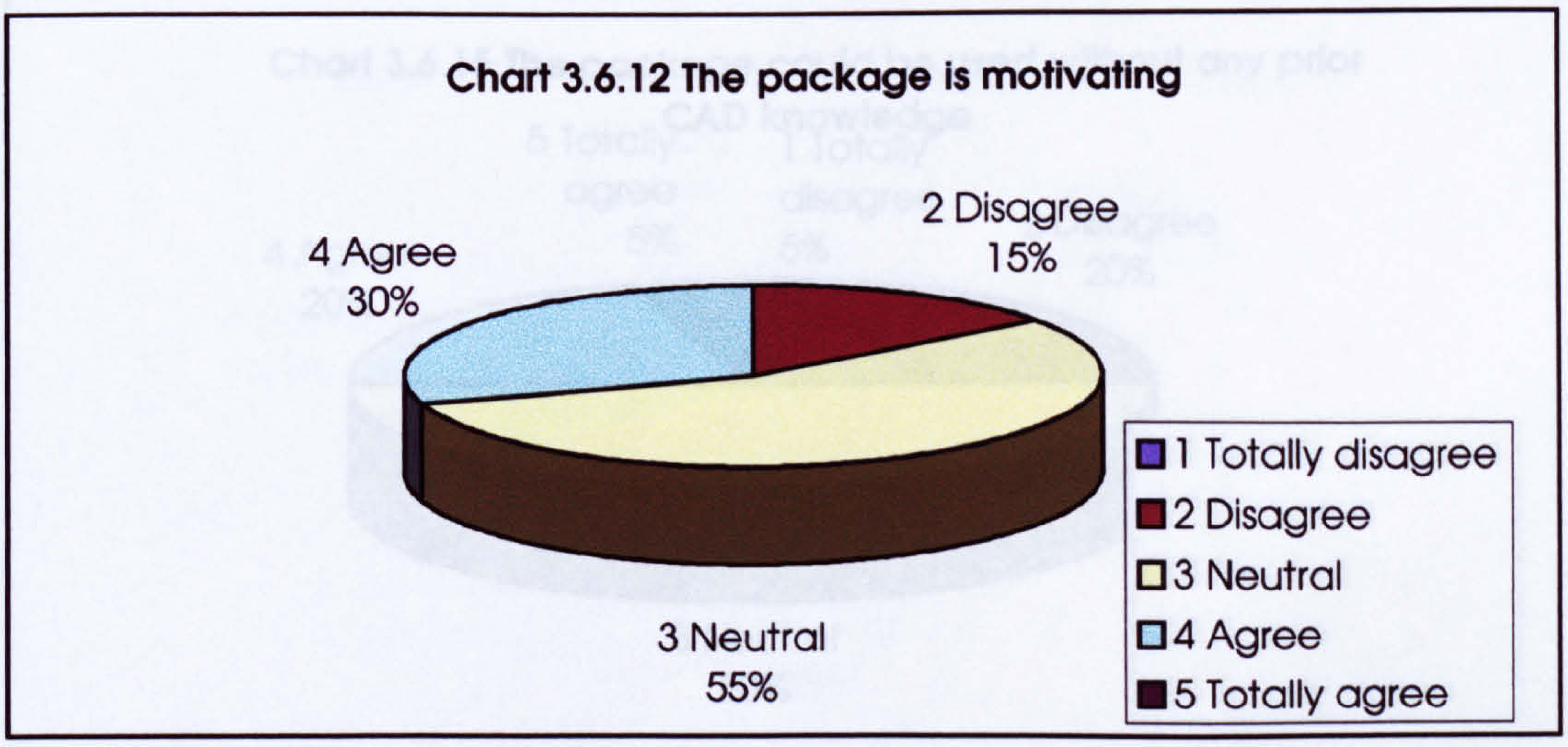




Using the package







CAD Skills

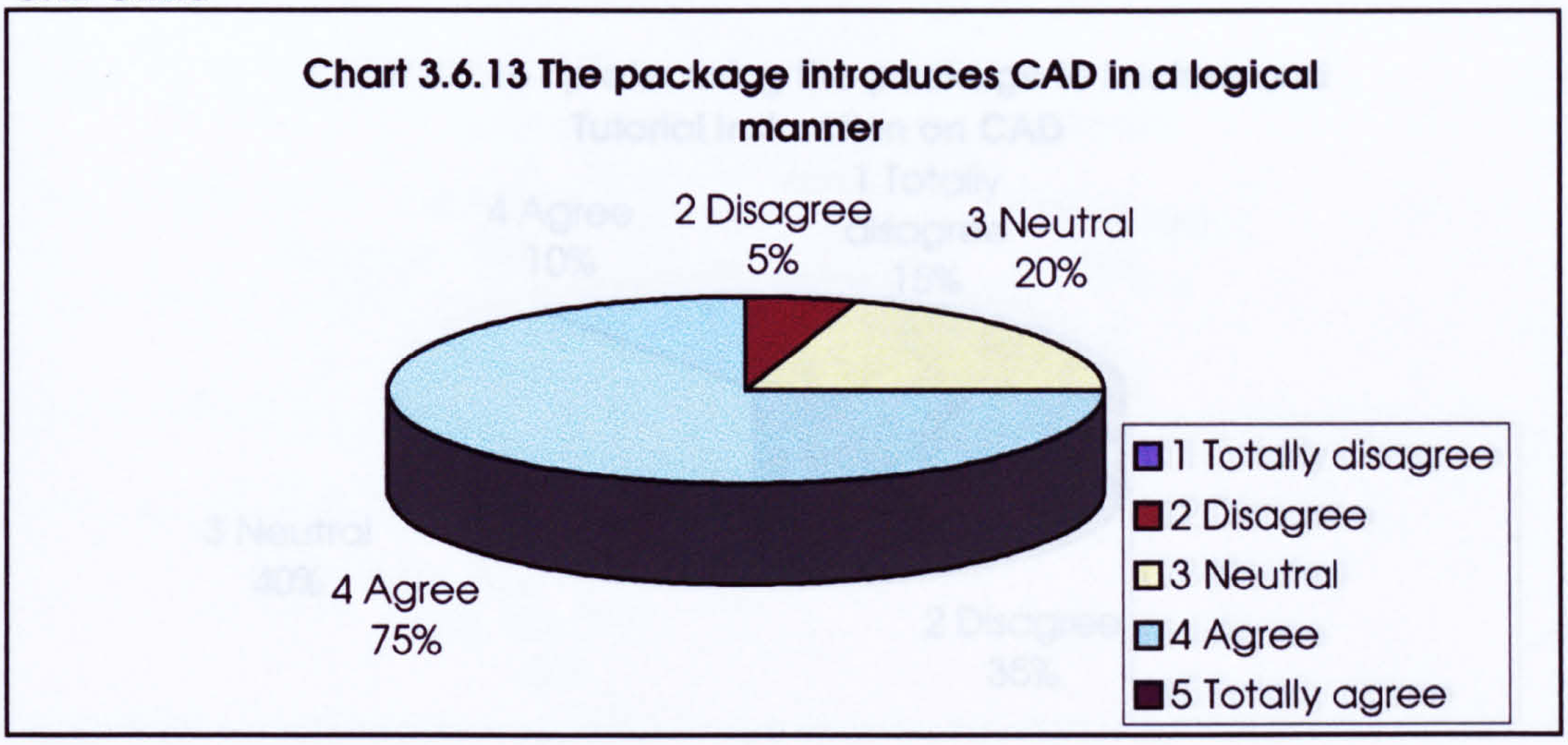


Chart 3.6.13 The package introduces CAD in a logical manner
2 Disagree 5%
3 Neutral 20%
4 Agree 75%
1 Totally disagree
2 Disagree
3 Neutral
4 Agree
5 Totally agree

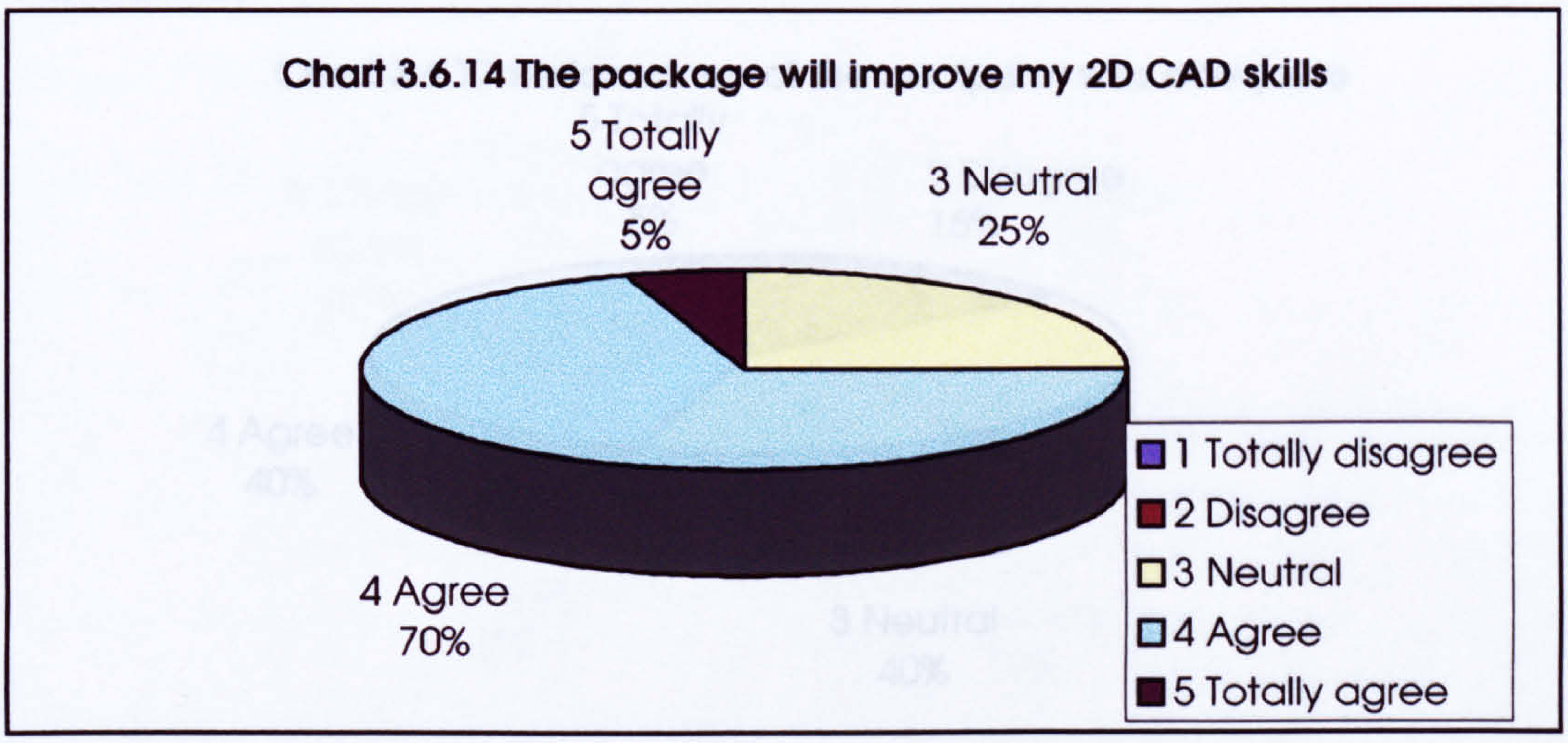


Chart 3.6.14 The package will improve my 2D CAD skills
5 Totally agree 5%
3 Neutral 25%
4 Agree 70%
1 Totally disagree
2 Disagree
3 Neutral
4 Agree
5 Totally agree

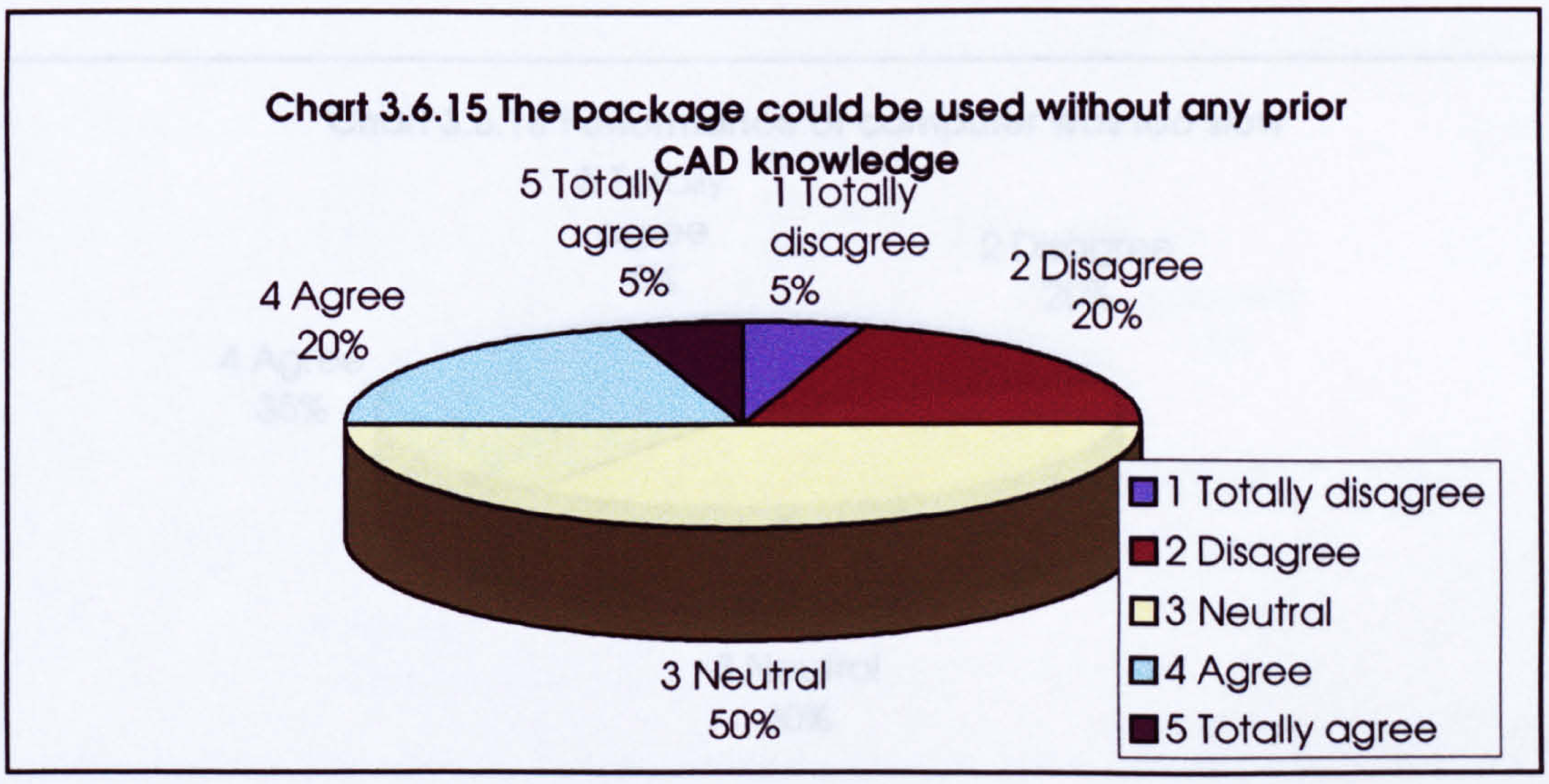
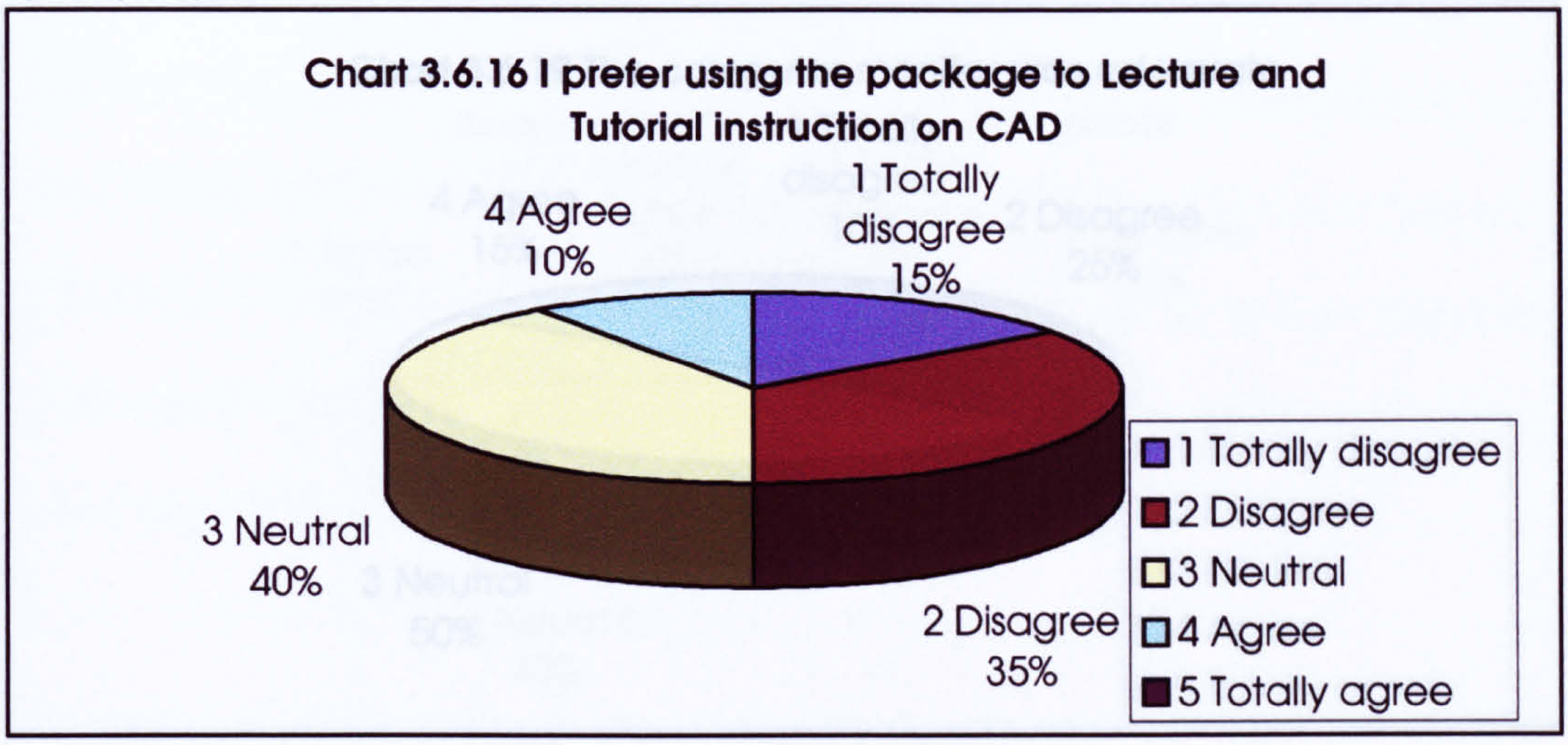
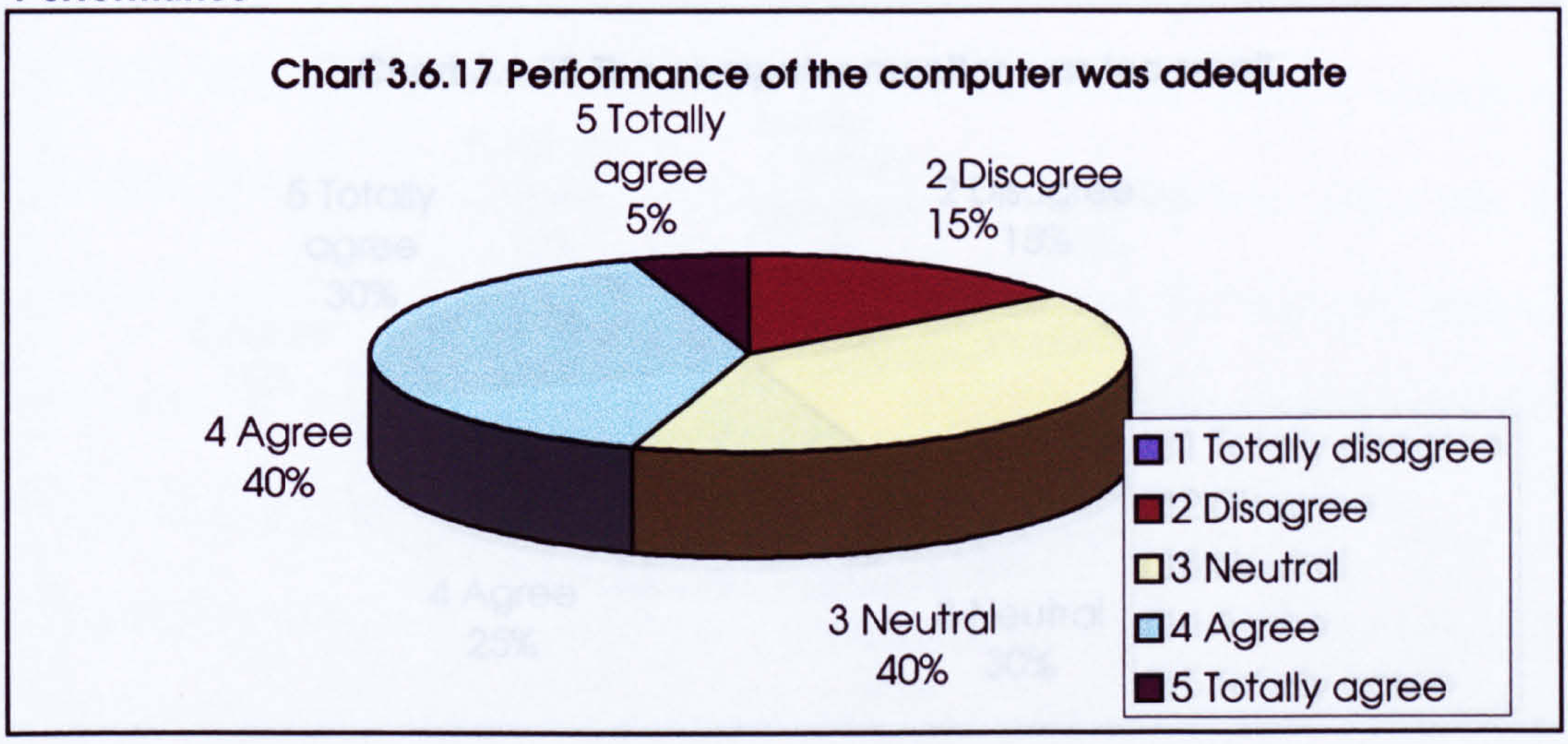


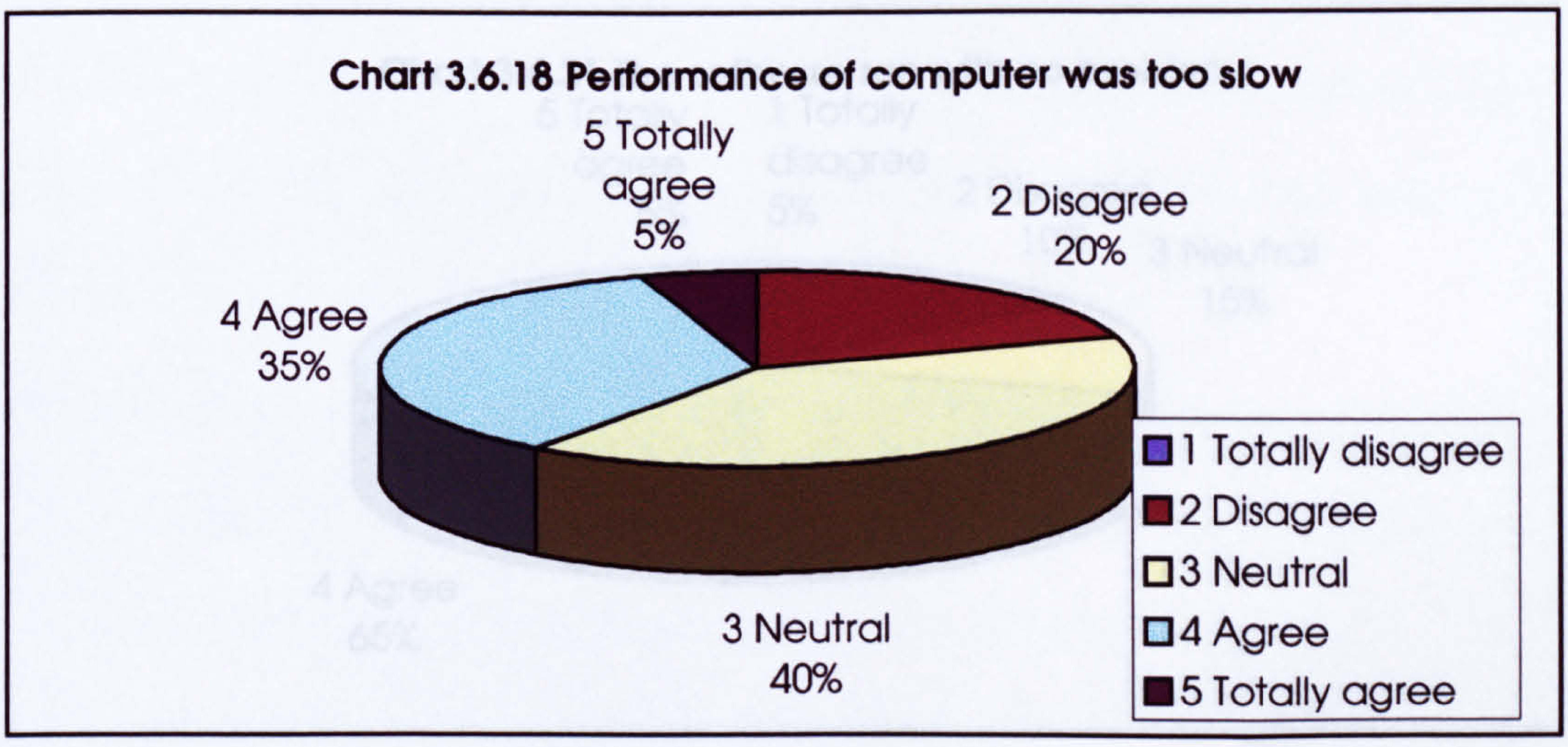
Chart 3.6.15 The package could be used without any prior CAD knowledge
5 Totally agree 5%
1 Totally disagree 5%
2 Disagree 20%
4 Agree 20%
3 Neutral 50%
1 Totally disagree
2 Disagree
3 Neutral
4 Agree
5 Totally agree

CAD Skills

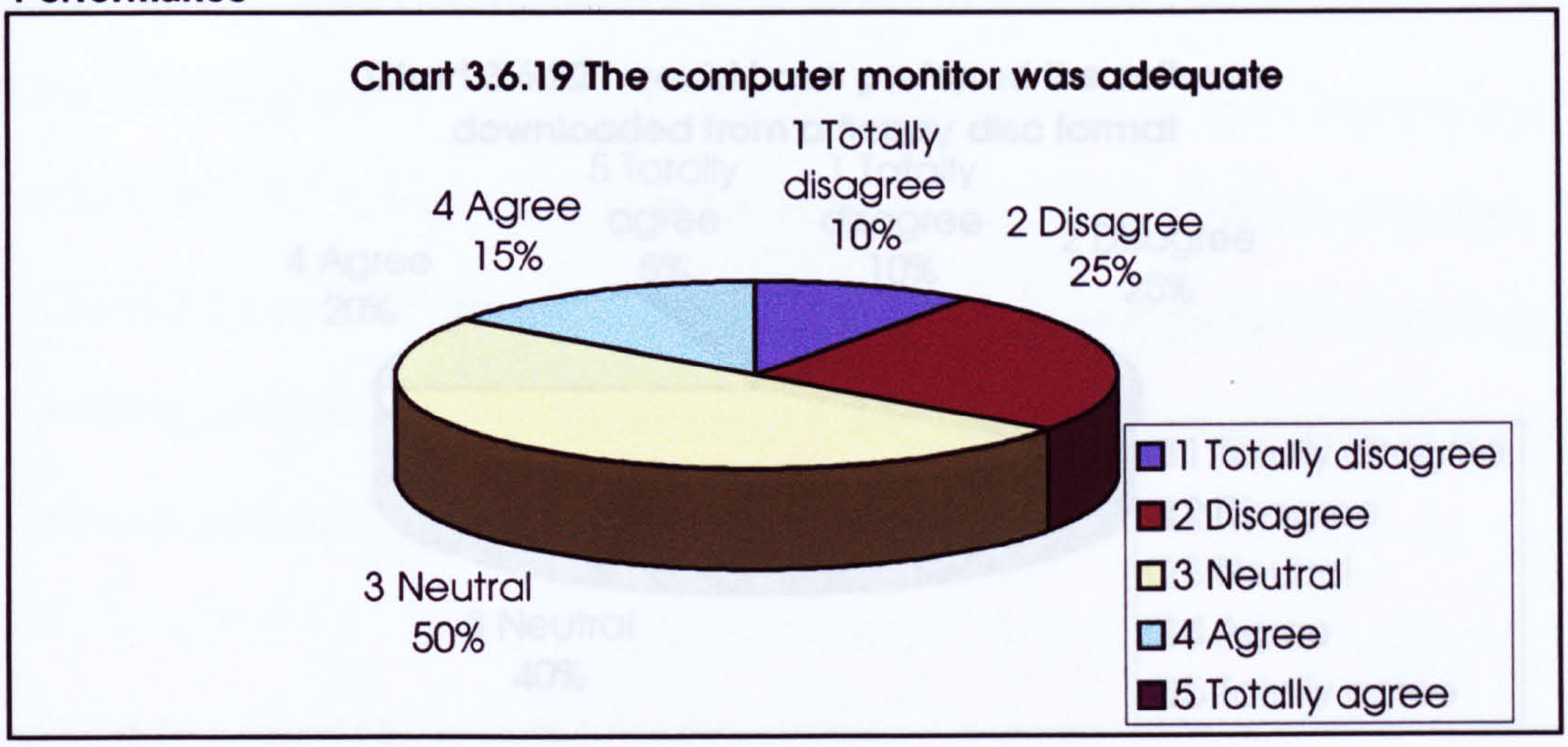


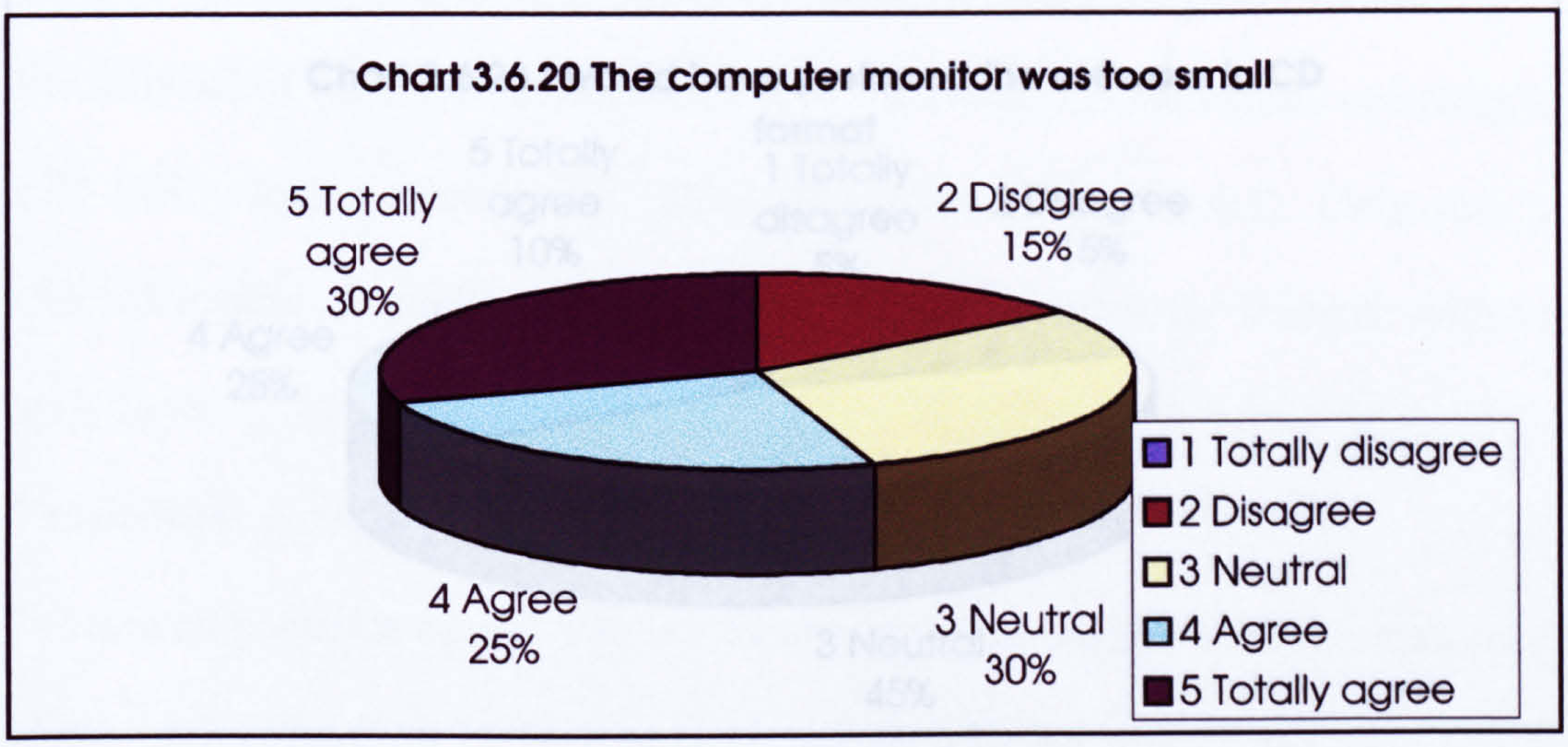
Performance

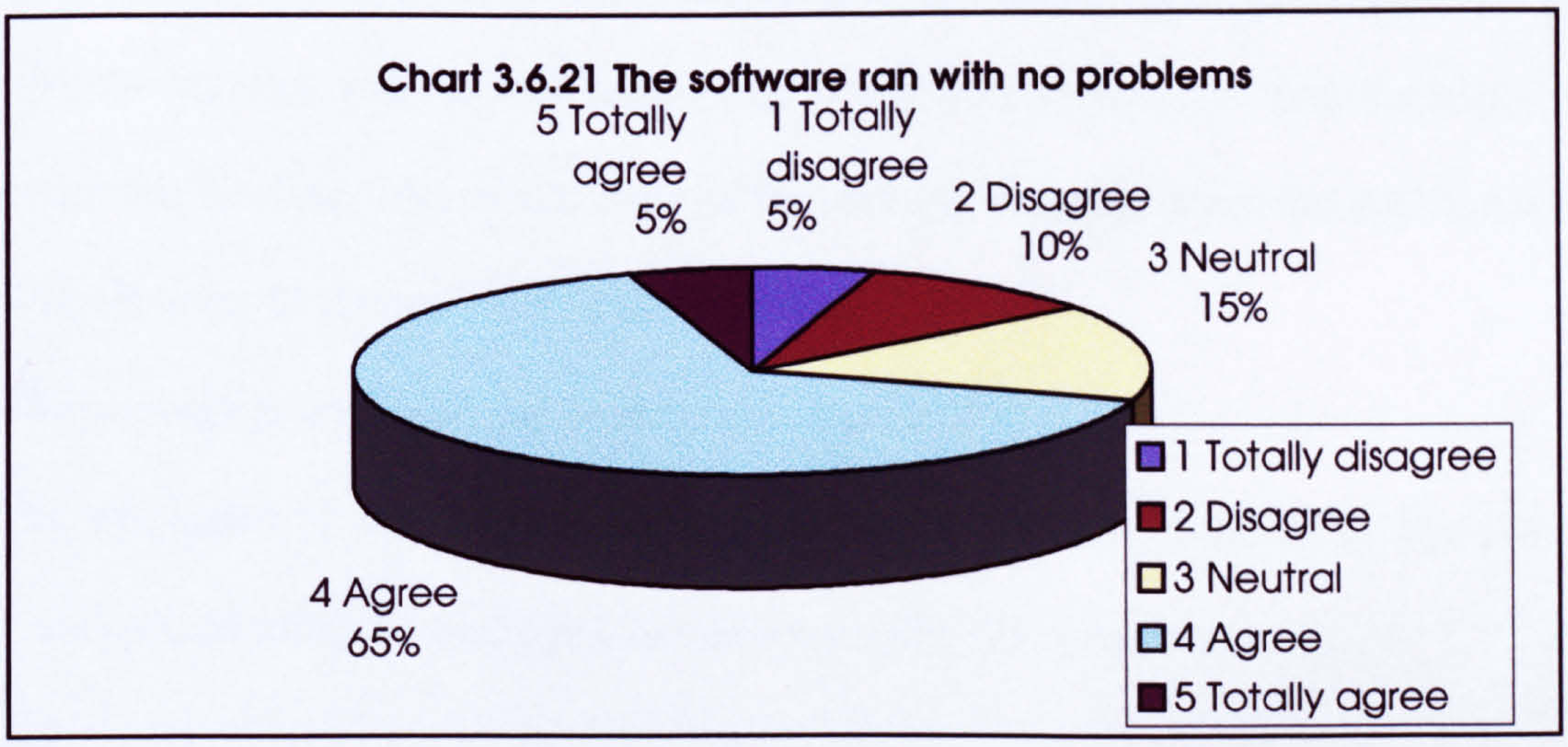




Performance







Performance

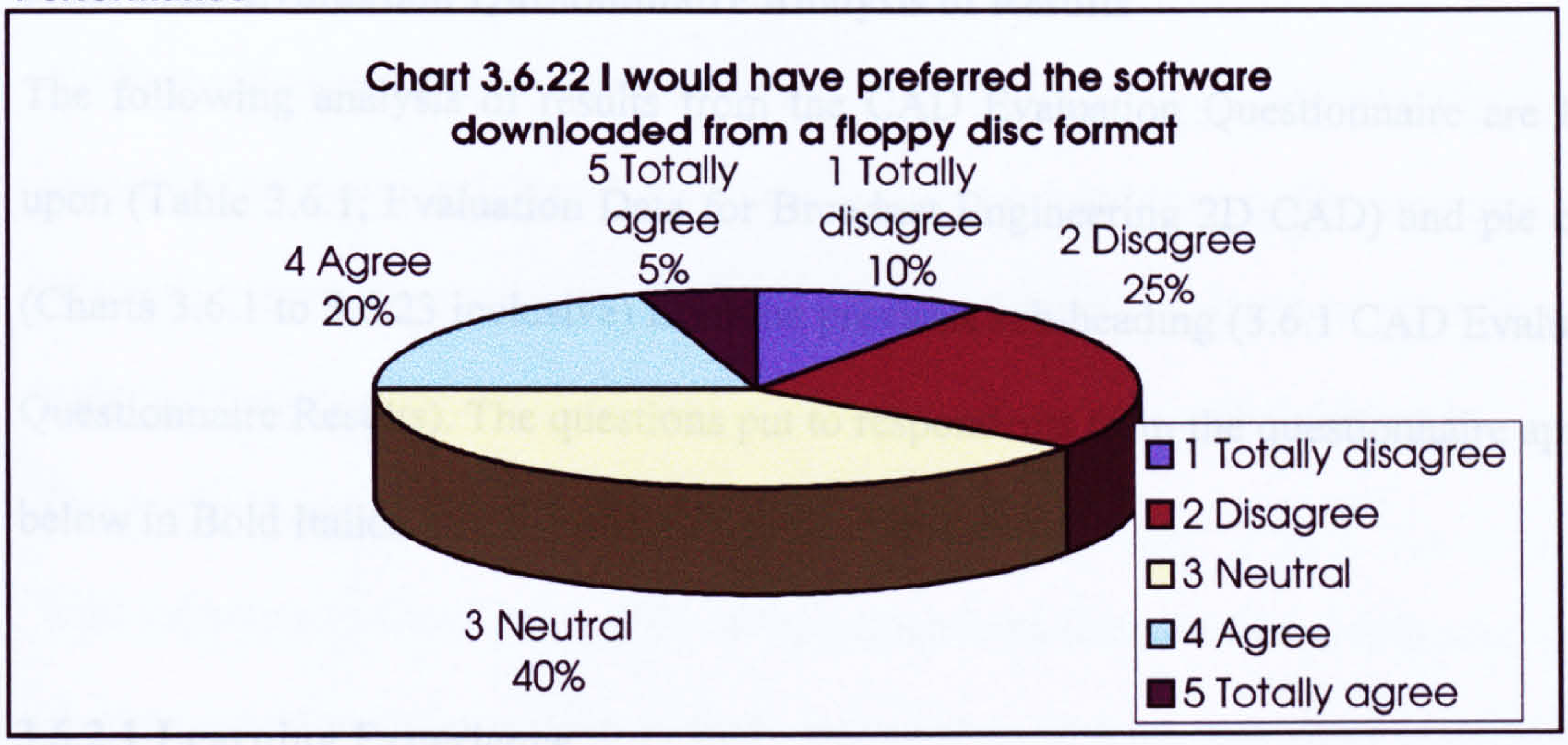


Chart 3.6.22 I would have preferred the software downloaded from a floppy disc format

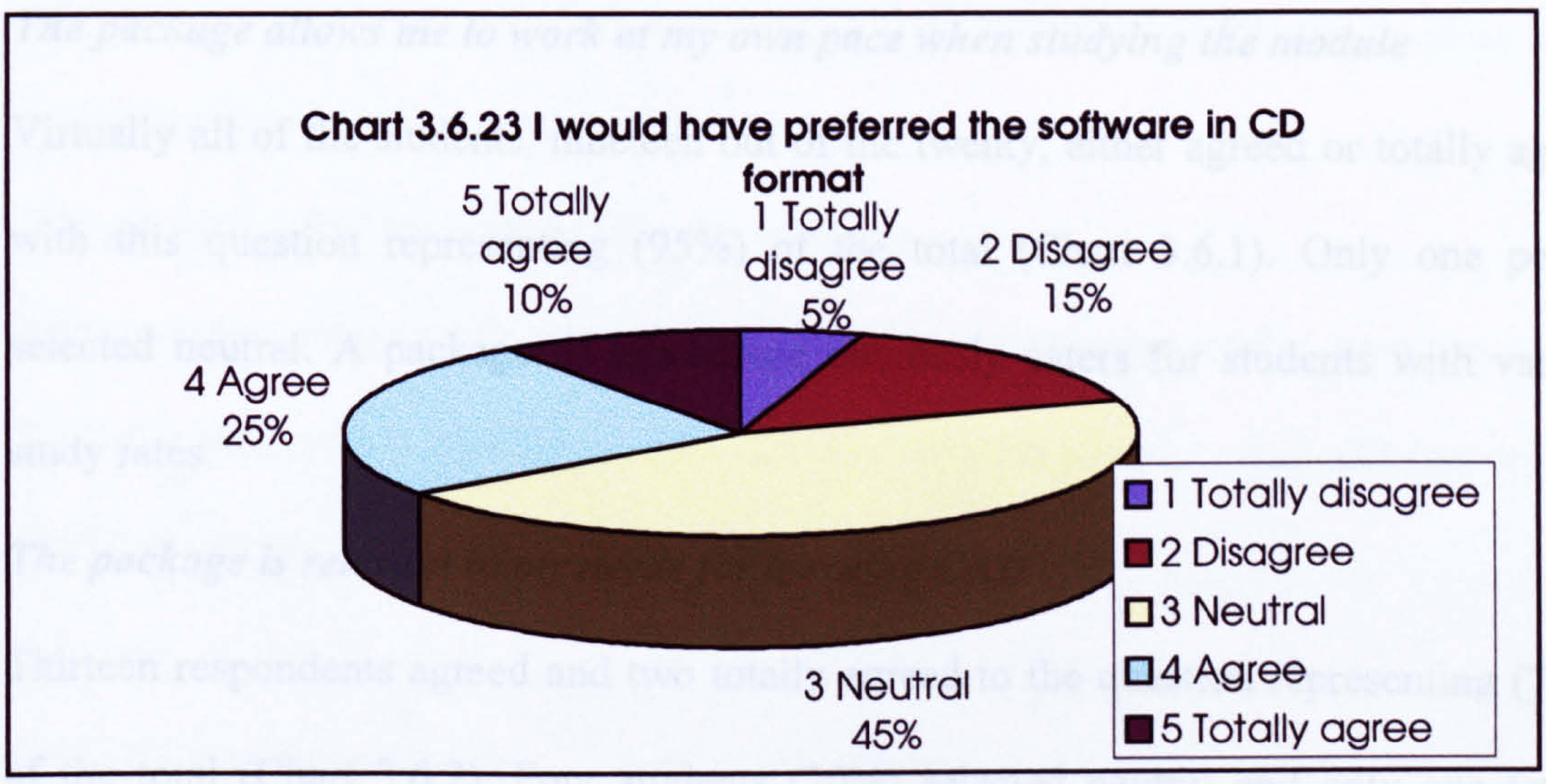


Chart 3.6.23 I would have preferred the software in CD format

3.6.2 CAD Evaluation Questionnaire Analysis of Results

The following analysis of results from the CAD Evaluation Questionnaire are based upon (Table 3.6.1, Evaluation Data for Broadnet Engineering 2D CAD) and pie charts (Charts 3.6.1 to 3.6.23 inclusive) from the previous sub-heading (3.6.1 CAD Evaluation Questionnaire Results). The questions put to respondents from the questionnaire appears below in Bold Italics.

3.6.2.1 Learning Experience

The package allows me to work at my own pace when studying the module

Virtually all of the students, nineteen out of the twenty, either agreed or totally agreed with this question representing (95%) of the total (Chart 3.6.1). Only one person selected neutral. A package of this nature obviously caters for students with various study rates.

The package is relevant to my needs for learning CAD

Thirteen respondents agreed and two totally agreed to the question representing (75%) of the total (Chart 3.6.2). Four students (20%) selected neutral and only one totally disagreed. Overall a positive response; however, the one student who totally disagreed with the question was the only respondent to totally disagree to the next three questions under this heading. This would indicate the learning experience and the package wasn't suitable to his CAD needs for whatever reason.

The package gives useful guidelines for using CAD

The responses to this question (Chart 3.6.3) are virtually identical to the previous question indicating the package guidelines for using CAD was about right.

The package gives me flexibility to study at anytime

A very positive response to this question 85% of the respondents either totally agreed or agreed to this question (Chart 3.6.4). One student summed it up in his comment section "I totally agree because of the 24 hour Internet access". A number of students also indicated that they had accessed the CAD package from home via the Internet.

The package would encourage me to study alone more

With reference to Chart 3.6.5, 45% of the respondents (nine students) indicated that the package would encourage them to study alone more, with another eight students (40%) selecting a neutral response. Just three students (15%) indicated that the package would not encourage them to study alone more.

The package gives me control over my learning

Sixty per-cent respondents representing eleven students either totally agreed or agreed with this statement (Chart 3.6.6), six students (30%) remained neutral and two students (10%) disagreed. Overall a positive response to the question.

3.6.2.2 Using the package

The package is useful

It was encouraging to see (Chart 3.6.7) that of the majority of students 80% (sixteen students) found the package useful, two students (10%) selected neutral and only two students (10%) disagreed with the question.

The instructions provided with the package make it easy to use

With reference to Chart 3.6.8 only one student disagreed with this and five students (25%) selected neutral, the remaining fourteen respondents accounting for 70% agreed that the instructions provided made the package easy to use.

The package is enjoyable

Ten students representing (50%) remained neutral to this question (Chart 3.6.9). Two students (10%) disagreed and one (5%) totally disagreed. The remaining seven students (35%) agreed that the package was enjoyable. Overall one could argue that as an educational piece of software the package was enjoyable to use. However, if compared with playing a game on a computer, the word "enjoyable" maybe perceived in a different manner.

The content material / activities contained in the package are too simple

Two students (10%) disagreed with the question and ten students (50%) remained neutral to this question (Chart 3.6.10). The remaining eight (40%) either agreed or totally agreed that the content material/activities in the package were too simple. It could be argued that the material has been designed to teach and develop basic 2D CAD skills to a range of students and thus bring them up to the same level without them requiring to master its complete functionality. These CAD skills are tested and assessed by the students being able to complete the drawing exercises built into the package and further design assignments in other modules that require the students to provide 2D CAD working drawings of their designs to an appropriate BS308 standard. However, if need be more difficult example drawings could be included into the package to alleviate this.

The package is interesting

Eight students representing (40%) indicated that the CAD package was interesting (Chart 3.6.11). Ten students representing (50%) adopted a neutral response and the other two students (10%) disagreed with the question.

The package is motivating

Chart 3.6.12 indicates that only one student didn't find the package motivating, with the largest number of students, eleven, representing (55%) of the respondents, opting for neutral. The remaining six students (30%) agreed that the package was motivating.

3.6.2.3 CAD Skills

The package introduces CAD in a logical manner

A very positive response to this question with fifteen respondents (75%) agreeing with the question (Chart 3.6.13). Four respondents chose neutral (20%) and one of the respondents disagreed.

The package will improve my 2D CAD skills

Again a very positive response to this question (reference Chart 3.1.14) with fifteen respondents (75%) either agreeing or totally agreeing with the statement. No respondents disagreed, five (25%) indicated a neutral response.

The package could be used without any prior CAD knowledge

With reference to Chart 3.6.15 the responses appear as a fifty-fifty split i.e. from the figures ten respondents (50%) indicated a neutral response with an exact equal amount of respondents either agreeing or disagreeing with the question. Therefore it could be argued that half the group felt the package could be used without any prior CAD knowledge and the other half did not.

I prefer using the package to Lecture and Tutorial instruction on CAD

This was considered to be an important question in the light of CAL developments. Reference Chart 3.6.16, ten students (50%) disagreed or totally disagreed with this question, eight students (40%) remained neutral and only two students (10%) agreed. These figures would indicate that a larger part of these students preferred lecture and tutorial instruction to a package of this nature or saw a role for traditional teaching methods working in conjunction with a CAL package.

3.6.2.4 Performance

Much of the early development work took place on '486' machines and although the CAD package had run successfully within the engineering section during the final development stage on early 'Pentium' machines, the questions were to determine if the performance of the computers in the department were satisfactory for the task in hand from the students' point of view.

Performance of the computer was adequate

Reference Chart 3.6.17, three students (20%) felt that the performance of the computers was unsatisfactory with a further eight (40%) selecting a neutral response. Nine students (45%) indicated the performance was adequate.

Performance of the computer was too slow

Eight students (40%) agreed with the statement and a further 40% selecting a neutral response. Four students (20%) found the speed of loading drawings etc satisfactory

The computer monitor was adequate

Chart 3.6.19 indicates that the computer monitor was inadequate for seven of the students (35%) with a further ten students (50%) indicating a neutral response. Only three students (15%) indicated the monitor being adequate.

The computer monitor was too small

The majority of the respondents (eleven 55%) felt the computer monitor was too small (Chart 3.6.20). Six students (30%) selected neutral and only three students (15%) indicated that the size of the monitor was adequate.

With regard to monitor size at the time of the evaluation the computers used by the students for the CAD package consisted of a mixture of 14" and 17" size monitors which would account for the responses to the questions on computer monitors.

The software ran with no problems

Reference Chart 3.6.21, fourteen students (65%) indicated that the software ran with no problems, three students (15%) selected neutral and three students (15%) had problems when running the software.

The initial problems appeared when students originally logged into the package because of the password control. This has since been rectified to accept the unique University number belonging to the student. The other problems tend to arise when students fail to set up a directory/folder in which the CAD drawings are periodically downloaded from the Broadnet server and located in the student's directory/folder. A number of students managed to crash the computer or lock it out completely, usually due to the infinite number of 'Windows' they had open at any one time.

I would have preferred the software downloaded from a floppy disc format

Seven respondents (35%) disagreed or totally disagreed with this question (Chart 3.6.22) having preferred the existing system. Eight respondents (40%) selected neutral and five respondents indicated they would have preferred the software downloaded from floppy disc. With hindsight this question is probably redundant in that the byte size of the software would require a significant amount of discs to be involved. The now reduced costs of producing the software in CD format give the next question more credibility.

I would have preferred the software in CD format

With reference to Chart 3.6.23 seven students (35%) either agreed or totally agreed with the question preferring a CD to work from. Nine (45%) selected a neutral response and four (20%) either disagreed or totally disagreed with the question.

At the time of the CAD questionnaire evaluation only a few of the students who took part had access to the Internet compared with today, the idea of taking a CD home to work on in their own time at their leisure therefore probably appealed to them. The added advantage of no cost by not having to access the Internet from home is also a bonus. There has been no provision to date to provide the Broadnet Engineering 2D CAD package in CD format, the main reason due to its ease of access over the Internet and its free use whilst on the University computer network.

3.6.3 CAD Package Evaluation Summary

The downside is the amount of time, effort, and commitment needed in producing a package of this nature. Many authors of CAL software report that 100hours – 300hours development time is needed for 1hour of CAL material. The author submitted the original proposal to develop the package in 1996; work began on developing the courseware in early 1997 on a part-time basis by a colleague and the author and a programmer inputted the material. Over 1000 man-hours were spent in developing and refining the package to its final evaluation by students in early 1999.

Overall, the package for learning and teaching 2D CAD has been very successful and the students' responses via the questionnaire were in the main positive towards it.

It is recognised that a different distribution of results may possibly have been obtained if a larger number of students from different courses had been used when conducting the evaluation questionnaire. However, since the evaluation took place the package has been used successfully on undergraduate, MSc and short courses for teaching 2D CAD skills.

The performance of computers and size of monitors was one area in which students and staff showed concern and computers have since been replaced, during 1999/2000, with larger monitors. Like all CAD packages the larger the monitor and speed of the computer the better the working environment, especially a package of this nature, which relies on the AutoCAD assistant window being open and running in unison with the AutoCAD software.

When the package is used during class periods tutor support is made available for students who get-into any difficulties. However, most problems tend to arise when some students use the package for the first time, logging in and downloading the CAD drawings from the University Broadnet server to an appropriate directory i.e. they often haven't read the instructions.

The layout and content of the CAD Evaluation Questionnaire was deemed successful because it was concise and to the point in establishing the evaluation criteria from the students point of view, in terms of the Learning Experience, Using the Package, CAD Skills and Performance. The general layout of the Questionnaire could be used with slight wording modifications for evaluating other CAL software.

The main benefits of a package of this nature are that it caters for: -

- The different pace at which students' work.
- Student different learning needs in developing transferable skills i.e. they can repeat sections or skip or go to a harder section in developing their CAD skills.
- Flexibility to study at anytime.
- Access over the Internet.
- Large number of students.

- Assessment provided in the way of drawing examples which students should be able to complete once they have worked through the package.

Some of these findings are endorsed by [25]Brandon et al (Sept 1994 p.67) who state "Allowing students access to CAL material is an excellent way in overcoming the problem of differing student ability levels, gives the student an opportunity to travel through a learning experience at his or her own speed, giving them the information they require at an instant and the opportunity of self-testing until they have reached a level of competence that they are happy with"

[26]The Broadnet Project Evaluation Report (June 1998 p.36) gave benefits of the delivery system as "By delivering this service to the desktop, people who cannot access training or information from more conventional sources due to time constraints or location can be supplied with the service at a time that suits them" and "Its ability to widen participation in the Information age"

One of the main objectives was to develop a CAD learning and teaching package that interfaced with a commercial piece of software, in this case 'AutoCAD', and would not become obsolete quickly once the commercial software was upgraded. To date the commercial software has been upgraded and the package has still functioned satisfactorily without requiring modifications.

The following plate shows the design layout and animation of a car dashboard by 1st year CAPD students using AutoCAD. The animation was carried out using the Script file facility in the software, this highlights the ergonomic layout and how the steering wheel will obscure the instruments when turning.

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[25] BRANDON, J. A. and EVANS, I. C. (September 1994) *Teaching Foundation Course Students – A Better Way!* Alternative Approaches to Teaching Engineering Volume 1. Edited by Ivan Moore and Kate Exley. The Engineering Professors Council with The UK Universities and Colleges Staff Development Agency, Sheffield,UK. p.67.

[26] *The Broadnet Project: Evaluation Report.* (June 1998) The University of Wolverhampton, UK. Report Authors: 'Future Perfect Associates' p.36.

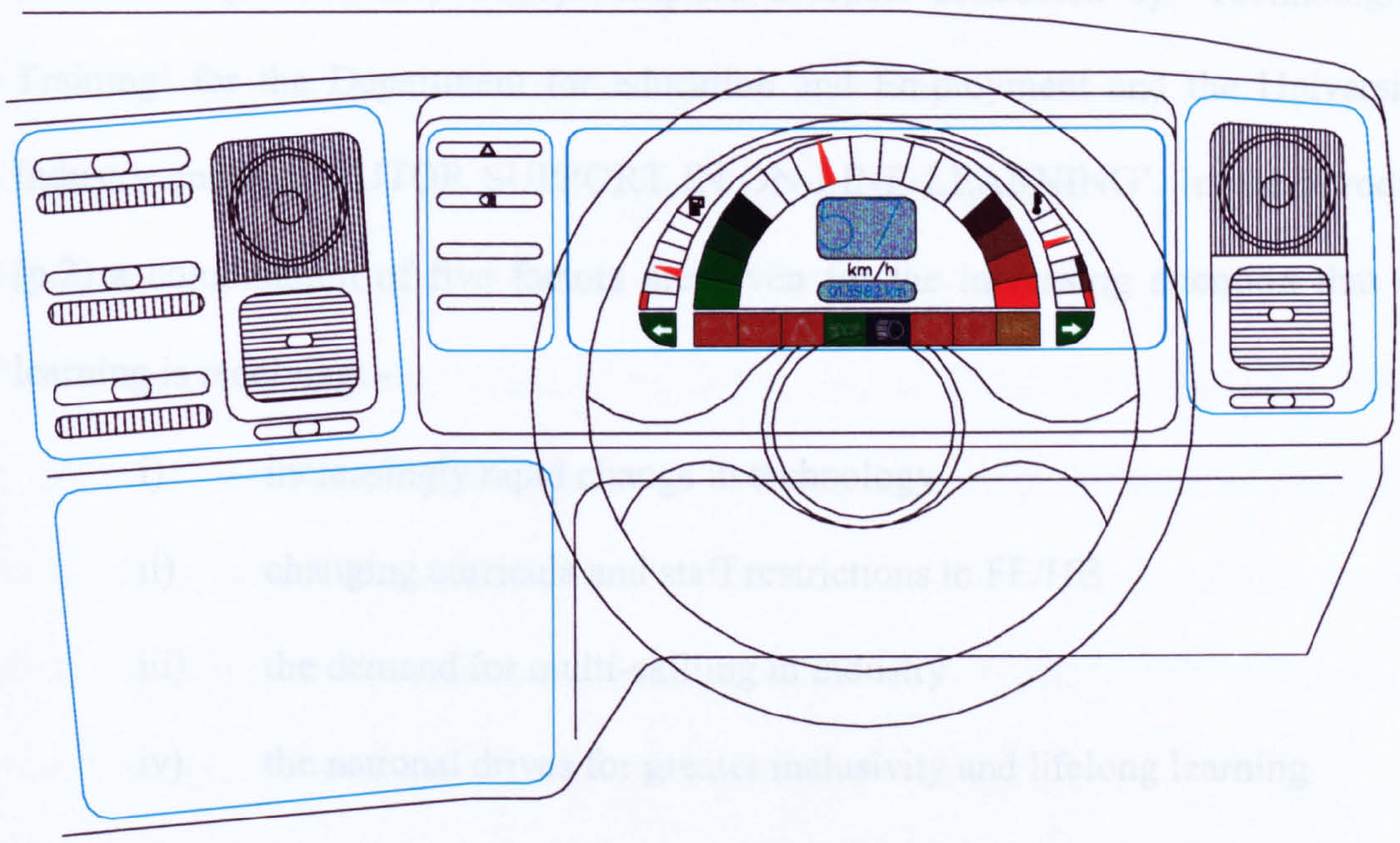
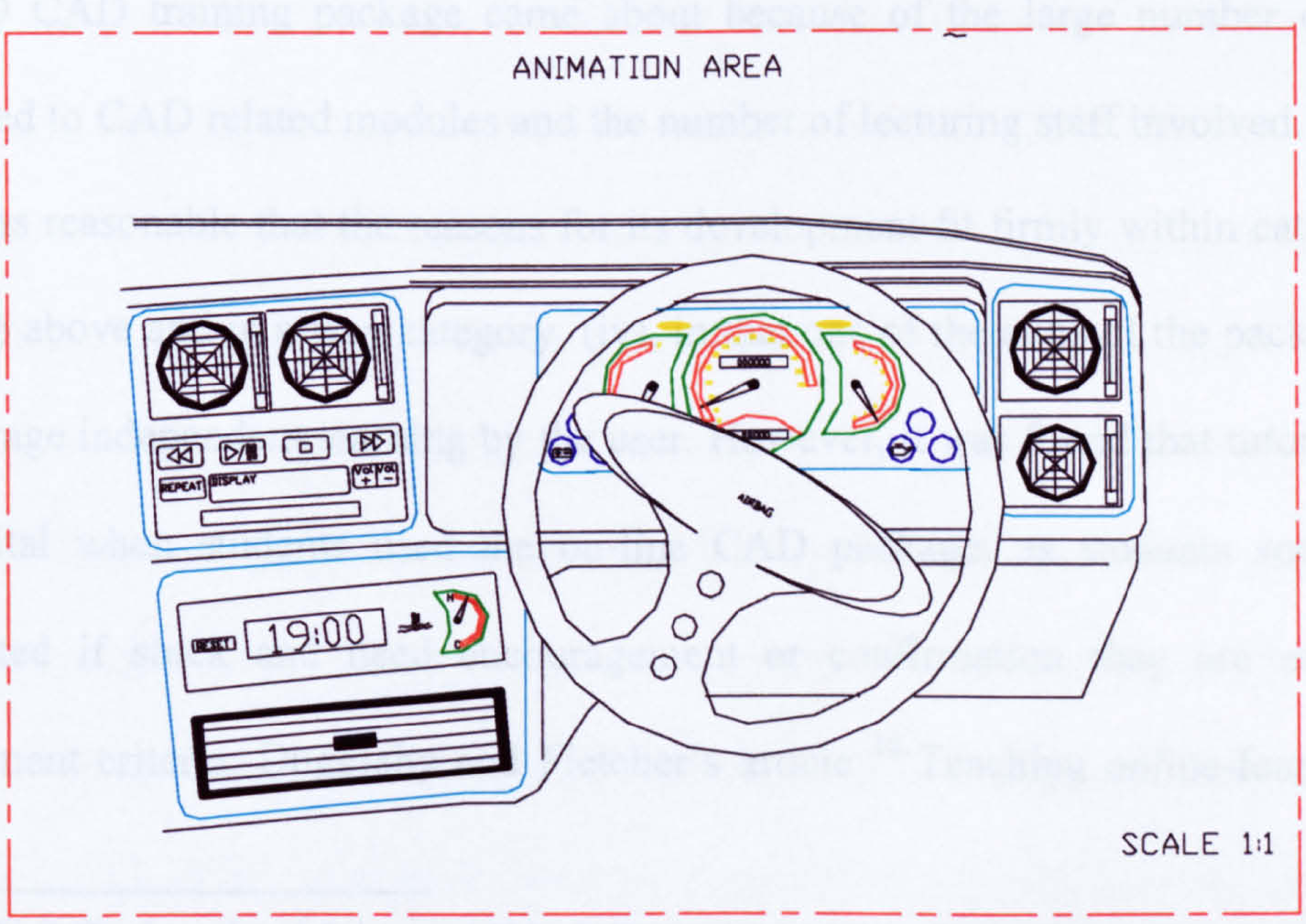


Plate 3.1 Dashboard design animations using Script file facility within AutoCAD software. 1st Year BSc CAPD, CAD Applications module. Top view shows Digital Dashboard layout. Bottom view shows conventional Analogue type of layout.



3.7 Innovative Approaches To Teaching And Learning, Conclusions

[27]Whitlock (1st February 2000) compiled a report conducted by 'Technologies for Training' for the Department for education and Employment and the University for Industry entitled "TUTOR SUPPORT IN ON-LINE LEARNING'. In the introduction (p.2) a combination of five factors are given for the increasing attention that online learning is receiving: -

i) increasingly rapid change in technology

ii) changing curricula and staff restrictions in FE/HE

iii) the demand for multi-skilling in industry

iv) the national drives for greater inclusivity and lifelong learning

v) the constant search for economies to cope with greater number of students

As previously discussed at the start of this chapter (3.5.1) the proposal for developing the 2D CAD training package came about because of the large number of students attracted to CAD related modules and the number of lecturing staff involved. Therefore, it seems reasonable that the reasons for its development fit firmly within categories (ii) and (v) above and in a way category (iv), in that one of the aims of the package was to encourage independent learning by the user. However, it was found that tutor support is still vital when students used the on-line CAD package, as students soon become frustrated if stuck and need encouragement or confirmation they are meeting the assessment criteria. Duggleby and Fletcher's article [28]'Teaching online-fear not' (July

[27] WHITLOCK, Quentin. (1 February 2000) *TUTOR SUPPORT IN ON-LINE LEARNING*, A report to the Department for Education and Employment and the University for Industry on a literature search, conducted by 'Technogies for Training' UK. pp.2-3.

[28] DUGGLEBY, Julia and FLETCHER, Tony. (July 2000) *Teaching online – fear not* 'The Lecturer' journal, Higher Education Section. Editor Paul Mackay. London: Landmark Publishing Services, p.18.

2000) would support this, the article discusses that it is nonsense to believe that tutors will be superfluous once course materials are available on the Internet. The article points out "People want the guidance of a tutor. They want access to someone, an expert, who has the experience and knowledge to guide their learning, to motivate them, to congratulate them on their success, and to point out their errors".

Fifty per cent of students who took part in the CAD evaluation questionnaire would further support this, under sub-heading (3.6.2.3 CAD Skills) they disagreed with the question "I prefer using the package to lecture and tutorial instruction on CAD" a further forty per cent remaining neutral to the question. The findings suggest that CAL packages require tutor support and need to work in conjunction with traditional and other teaching methods and not replace them in their entirety.

With reference to item (v) above 'the constant search for economies to cope with greater number of students' there appears to be little true costing made available in the development and delivery of CAL packages. This could form a good basis for further research. As previously mentioned, well over 1000 man hours went into the 2D CAD learning and teaching package to make it a success, much of this in the Lecturer's own time. If costing were carried out just on a Lecturer's hourly rate alone this would equate to a full time Lecturer's salary for one year. It could be argued however, that once the package is set up the cost of running it is minimal.

CAL packages dealing with areas such as Mathematics and Languages may be more cost effective than some Product Design areas, in that content does not change to a great extent i.e. Mathematics principles and Languages remain the same. In the case of Engineering, however, new developments, especially CAD and Product Design and Development, move at a rapid rate and this needs to be taken into account when developing the material as it can quickly become obsolete.

Many CAD vendors today recognise the need for some form of on-line training in their software and are building CAD tutorials within their software's 'Help' facility, along with hyperlinks to their Web site and even on-line manuals.

[29]Whilock's report (1st February 2000 p.3) also describes three models proposed by [30]Fryer (1997) for on-line learning or Web-based training. The term E-Learning is used in the report to cover all of the three following categories: -

- The Desktop tutor, in effect computer based training (CBT) on the Web, often associated with job training and favoured by the corporate sector because the package is self contained with feedback exercises and needs little pedagogical support. However, it is now being widely accepted that having a tutor on duty or at hand gives added value and is important to its success.
- The "Online Class", through a planned series of activities tutors and students participate in online chats and other interactions by Email and Computer Mediated Communication. Often the learners are geographically widespread.
- The "Ultra Interactive Model" which incorporates video technology, real-time audio and videoconferencing with an instructor

This chapter of the thesis demonstrates the successful use and evaluation of all three forms of E-Learning in one form or another, which have taken place during the author's research in the area of Product Design. The learning and teaching package for 2D CAD fits within the first model and the use of Email, Fax, Videoconferencing, and making use of shareware software for the MSc course in Finland falls into the second and third models. It would seem feasible that the three models could be combined as technology

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[29] WHITLOCK, Quentin. (1 February 2000) *TUTOR SUPPORT IN ON-LINE LEARNING,* A report to the Department for Education and Employment and the University for Industry on a literature search, conducted by 'Technogies for Training' UK. pp.2-3.
[30] FRYER, Bronwyn. (September 1997) *Are you caught on the web?* Inside Technical Training. USA. pp. 10-15.

advances and become even cheaper. The learner accesses the on-line CAD learning package from a remote site or home via the Internet or local area network and has tutor support on-line, via either Email or one to one Videoconferencing.

The following gives a summary of advantages / disadvantages of CAL / Tutoring systems based upon these findings: -

Advantages of CAL /Tutoring System

- Open access, available at any time, geographical distance location become irrelevant.
- Student centred.
- Caters for different learning curves of students.
- Can be cost efficient once set up.
- Built in assessment.
- Can engage students in the sort of dynamic and interactive learning process favoured by most cognitive models of learning.
- Can present dynamic process i.e. objects viewed and rotated.

Disadvantages of CAL /Tutoring System

- Hardware can become obsolete very quickly.
- Software can become obsolete very quickly.
- Time factor in writing CAL software.
- Time factor in setting up system, testing etc.
- High initial cost incurred, consider capital and hidden costs such as maintenance and system management.

- Reliability, software if poor may break down, crashing due to poor programming and poor testing.
- Suitability. Is the software suitable for the task?

Chapter 4

4.0 The Role Of Industry

4.1 Background To The Company Questionnaire, Recruitment Criteria For Design Engineers And Product Designers

With reference to Appendix 4, the company questionnaire entitled "Company survey on recruitment criteria for Design Engineers and Product Designers", the questionnaire was designed to establish recruitment criteria and indicate the level of design skills companies look for or adopt when employing newly qualified Product Designers. The research findings aim to highlight any specific shortfalls in the design curriculum for product design, in particular with regard to the course BSc in Computer Aided Product (BSc CAPD).

4.2 Company Selection Criteria

Twenty-five companies were targeted to establish an appropriate contact person involved in recruiting designers for that company, e.g. a training manager or senior designer. The companies in question were selected because of their diverse product range when compared with one another, rather than different companies producing similar products. The reasons for selecting companies in this manner were based upon the following observations:-

i) The BSc CAPD curriculum was designed and developed for general product design to maximise employment chances for students in a diverse range of product design areas.

ii) Students wishing to specialise in a particular design field more suited to their intended career vocation had the facility of module options made available.

iii) The diverse range of Industrial Placements secured by BSc CAPD students both in the UK and abroad.

iv) Students' final year design projects could be tailored to their appropriate design field vocation.

v) Students graduated from the BSc CAPD course at the University of Wolverhampton and gained employment in various design disciplines in a number of companies that produced all types of services and products.

4.2.1 Company Response Rate

Out of the twenty five companies targeted, seventeen companies returned the completed questionnaire, only one returned it saying they could not help, thus giving a response rate of (17/25 * 100%) = 68%. This response was deemed very good and can be attributed to a number of factors:-

In the first instance a contact was established via telephone with an appropriate person within the company to allow the questionnaire and background to the research to be discussed. Secondly, following research into the format / layout of numerous questionnaires, the questionnaire was designed to be concise, to the point and completed quickly so the contact person didn't feel burdened by completing it. All too often, many questionnaires are tossed to one side or in the bin because they are complex, time consuming and difficult to fill in. It is for this reason the format was kept as simple as possible, based mainly around a tick box response to the questions.

Finally, to achieve good company returns it was deemed necessary to include a covering letter plus a pre-paid stamped addressed envelope to return the questionnaire.

4.3 Listing Of Company Product Range

The following lists the product range of companies who took part in the survey.

1. Power tools and Electrical Appliances.
2. Cars and 4*4 Vehicles.
3. Flight Control Equipment.
4. Electrical Installation Equipment.
5. New Product Development and Product Design.
6. Nut and Fastener Tightening Tools.
7. Locks.
8. Bathroom Products.
9. Vans and Pressings.
10. Mechanical Design for the Automotive Industry.
11. Showers and Mixer Valves.
12. Mini Excavators.
13. Fire Resisting Diskette Cabinets.
14. Speedometers and Tachometers.
15. Office Equipment.
16. Bus and Coach bodies.
17. Products for Aerospace and Petrochemical Industries.

4.4 Design Of The Company Questionnaire

At the start of the questionnaire the company name, company product and age group preferred for the post was requested. The latter was seen as important to establish if companies categorise people as either being too young and inexperienced or too old for the post.

4.4.1 Questionnaire Headings

The design of the completed questionnaire was focused upon seven specific headings concluding with two general headings as follows:-

1. **Educational background**
2. **Work Experience**
3. **Manual Drawing board ability and communication skills**
4. **Use of Computers in Design**

5. **Analysis of Design**
6. **Business**
7. **Manufacturing methods**
8. **What skills do you feel new designers are lacking ?**
9. **Any other comments**

These headings had been formulated from research based upon feedback from industry, student observations on industrial placements, the design curriculum and discussion with other members of design staff from the University on what might be perceived as appropriate skill areas necessary to become an effective practising Product Designer. The format of the questionnaire provided a provision upon which the level of skills the company felt were required when employing a newly qualified product designer could be analysed, the research findings possibly highlighting specific shortfalls in the design curriculum and forming the basis towards modifying modules and the design curriculum to improve undergraduate courses in Computer Aided Product Design.

1. **Educational background.** This included items such as minimum qualification for the post, area of product design and whether membership of a professional body was important.

2. **Work Experience.** The importance and merits of previous work experience is often seen as a necessity by recruitment personnel and academics, this section was designed to determine the companies policy regarding this.

3. **Manual Drawing board ability and communication skills.** Teaching students drawing skills on a manual drawing board is a contentious issue in the light of the developments in CAD, some design staff are for it and others against it. This section covered the general role of producing design sketches, being able to interpret /

produce working drawings and the building of physical models in foam, wood etc. thus communicating product design effectively in a 3 dimensional manner.

4. **Use of Computers in Design.** It is the author's opinion that this area is seen as one of the most important modern design tools available, the questions were directed to the usage and skill levels of general computing, 2 Dimensional CAD, 3 Dimensional CAD and surface modelling.

5. **Analysis of Design.** The questions assigned under this heading were an attempt to give an indication of the level of knowledge required when applying calculations to design problems. Examples to include the calculation of mass, volume, bending moments, stress analysis, finite element analysis and use of ergonomics i.e. "the study of the efficiency of persons in their working environment".

6. **Business.** This covered general business topics e.g. any Foreign Language requirement, Marketing, Advertising, Costing and working as a member in a Design Team.

7. **Manufacturing Methods.** This had the largest number of sub-headings, covering the general processes of casting, forging, presswork and welding followed by material properties of steels/plastics, the testing of materials, Computer Aided Manufacture (CAM), Robotics, Systems (hydraulics/pneumatics) followed by the contemporary techniques of Design for Assembly/Manufacture, Rapid Prototyping and Stereolithography.

8. **What skills do you feel new designers are lacking ?** An open question aimed at highlighting any skills the company thought was missing.

9. **Any other comments.** Question 9 gave the opportunity to cover any other important aspect or observation.

Questions under the Headings 3 to 7 inclusive were aimed at the Designer's Attributes and Qualities required for the position in the company. The level of skill proficiency required under these headings could be highlighted by ticking the appropriate box. The skill level ranged included: -

None	Basic	Competent	Good	Very Good
☐	☐	☐	☐	☐

4.5 Company Questionnaire Evaluation

4.5.1 Spreadsheet Format

The companies' responses to each question were evaluated by using spreadsheets to enter the data (Appendix 4, phd2\comp-cot.xls, Company Product and Responses). Each question was consecutively numbered 1 - 48, horizontally along the top of the spreadsheet and the list of 17 companies vertically down the side.

The following key was used for questions 1 - 12 of the questionnaire. This represented the companies' responses and was used to input data into the spreadsheet: -

1. Educational background

key 1 2 3 4 5 6 7
1. Minimum Qualification for post :- BTEC , ONC, HNC, HND, BSc, MSc, PhD

key 1 2
2. What study area is preferred by the company ? i.e. Product design, Electrical, Electronic, Mechanical, Manufacturing, Automotive etc.------------ALL--------------------
3 4 5 6 7

key 1 2
3. If an applicant has higher qualifications i.e. PhD would this put the company off ? *YES☐ NO☐*

key 1 2
4. Is graduate member of a Professional body important ? *YES☐ NO☐*

key ***1=Any 2=Mech***
5. If YES which professional body is preferred ?---

key ***1 2***
6. Is Chartered Engineer Status important once working for the company ? YES☐ NO☐

key ***1=Any 2=Mech***
7. If YES which professional body is preferred ?---

2. Work Experience

key ***1 2***
8. Is previous work experience essential ? YES☐ NO☐

key ***1,2,3,4,5,6, in years***
9. If YES minimal number of years------------------------------

key ***1 2***
10. Is the area of work experience important ? YES☐ NO☐

key ***1=appropriate to job, 2= Product Design, 3=Mech, 4=Automotive***
11.If YES what area of work experience is most appropriate for the company?----------

key ***1 2***
12. Is it important to have continuing professional development YES☐ NO☐

The following Key represented the companies responses to questions 13 - 48 (the tick boxes) and was used to input data into the spreadsheet:-

KEY	Input Number	Skill level
	0 represented	**None**
	1 represented	**Basic**
	2 represented	**Competent**
	3 represented	**Good**
	4 represented	**Very Good**

The spreadsheet-input data formed the basis in producing appropriate bar chart graphs for analysis of each of the 48 questions (4.6 Company Questionnaire Results). Also, a count of the number of companies who responded to each particular skill level for each of the questions was established on the Spreadsheet (Appendix 4, phd2\comp-cot.xls, Company Product and Responses) this allowed the results to be converted and tabled in a percentage format based upon the 17 companies. e.g.

Question 13	**None**	**Basic**	**Competent**	**Good**	**Very Good**
No of companies who Selected these skills	0	2	1	10	4
Converted Results	(0/17*100)	(2/17*100)	(1/17*100)	(10/17*100)	(4/17*100)
Results as a %	0	11.76	5.88	58.82	23.5

I.e. no companies selected **None,** 11.76% of the 17 companies selected **Basic,** 5.88% selected **Competent** and 58.82% selected **Good** with the other 23.5% selecting **Very Good** for that particular skill area.

4.6 Company Questionnaire Results

The following tables, **Table 4.1** and **Table 4.2,** provide an overview of how the companies responded to each particular question based upon an overall percentage of the number of companies who took part. **Table 4.1** highlight questions 1 - 12 and **Table 4.2** questions 13 - 48, the responses to each skill level.

The following bar chart graphs represent the findings based upon the companies' responses to each of the 48 questions.

	Results based upon a Percentage of the 17 companies who took part.								
Quest No	%	%	%	%	%	%	%	%	%
1	0	5.88	5.88	29.41	35.29	17.65	0	0	5.88
2	0	29.41	0	0	35.29	0	11.76	23.53	
3	0	29.41	64.71	5.88					
4	0	17.65	82.35						
5	76.47	5.88	17.65						
6	5.88	23.53	70.59						
7	76.47	5.88	17.65						
8	0	64.71	35.29						
9	41.18	5.88	17.65	0	5.88	17.65			
10	11.76	76.47	11.76						
11	17.65	29.41	29.41	17.65	5.88				
12	0	94	5.88						

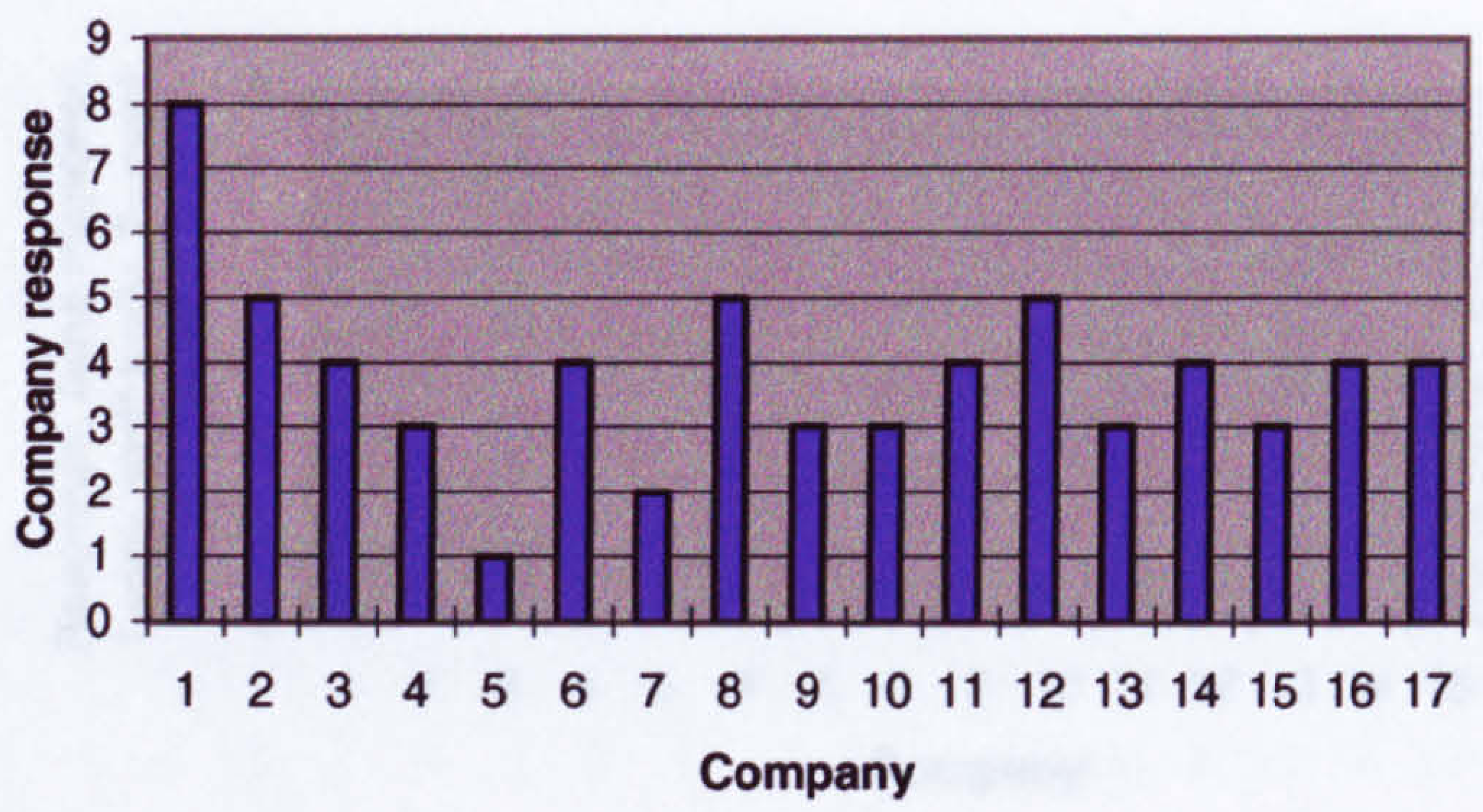
Table 4.1

	Results based upon a Percentage of the 17 companies who took part.				
Skill Level	None	Basic	Comp	Good	V Good
Quest No	%	%	%	%	%
13	0	11.76	5.88	58.82	23.53
14	0	0	5.88	41.18	52.94
15	0	5.88	35.29	29.41	29.41
16	0	11.76	17.65	41.18	29.41
17	0	0	5.88	41.18	52.94
18	23.53	23.53	23.53	29.41	0
19	29.41	23.53	35.29	5.88	5.88
20	0	5.88	23.53	47.06	23.53
21	0	5.88	0	35.29	58.82
22	5.88	11.76	47.06	11.76	23.53
23	11.76	35.29	11.76	23.53	17.65
24	0	17.65	29.41	23.53	29.41
25	0	17.65	17.65	47.06	17.65
26	17.65	5.88	35.29	23.53	17.65
27	23.53	17.65	23.53	17.65	17.65
28	5.88	17.65	17.65	35.29	23.53
29	35.29	35.29	17.65	11.76	0
30	70.59	17.65	5.88	5.88	0
31	17.65	0	23.53	52.94	5.88
32	5.88	35.29	17.65	35.29	5.88
33	41.18	35.29	17.65	5.88	0
34	0	11.76	17.65	52.94	17.65
35	0	5.88	11.76	64.71	17.65
36	0	5.88	11.76	35.29	47.06
37	0	0	0	35.29	64.71
38	0	11.76	11.76	47.06	29.41
39	11.76	0	11.76	41.18	35.29
40	0.00	11.76	41.18	29.41	17.65
41	11.76	11.76	35.29	35.29	5.88
42	5.88	35.29	35.29	17.65	5.88
43	17.65	47.06	23.53	11.76	0
44	5.88	35.29	29.41	23.53	5.88
45	11.76	35.29	29.41	5.88	17.65
46	0	5.88	17.65	17.65	58.82
47	0	5.88	17.65	5.88	70.59
48	11.76	41.18	29.41	11.76	5.88

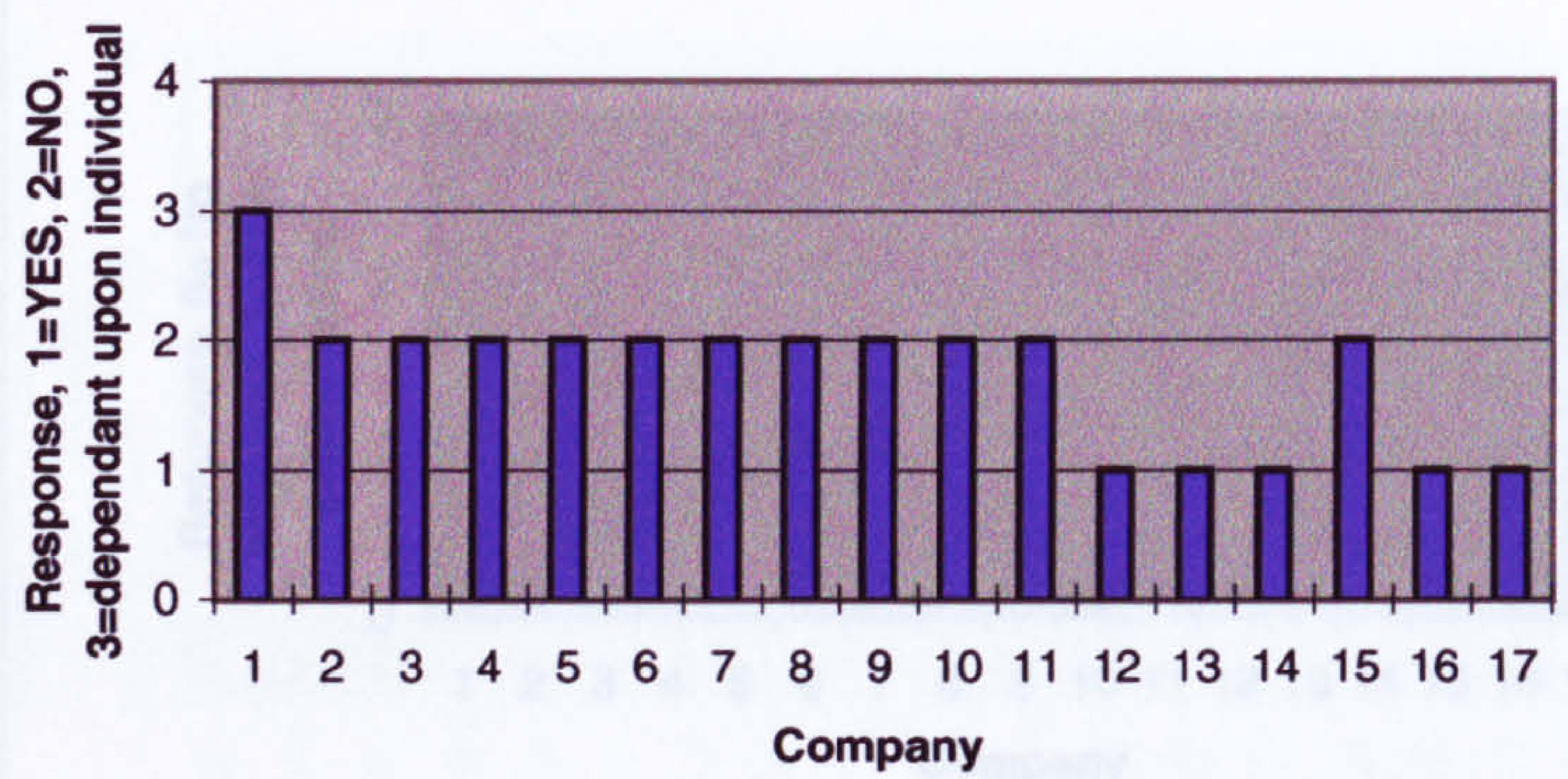
Table 4.2

1. Educational Background

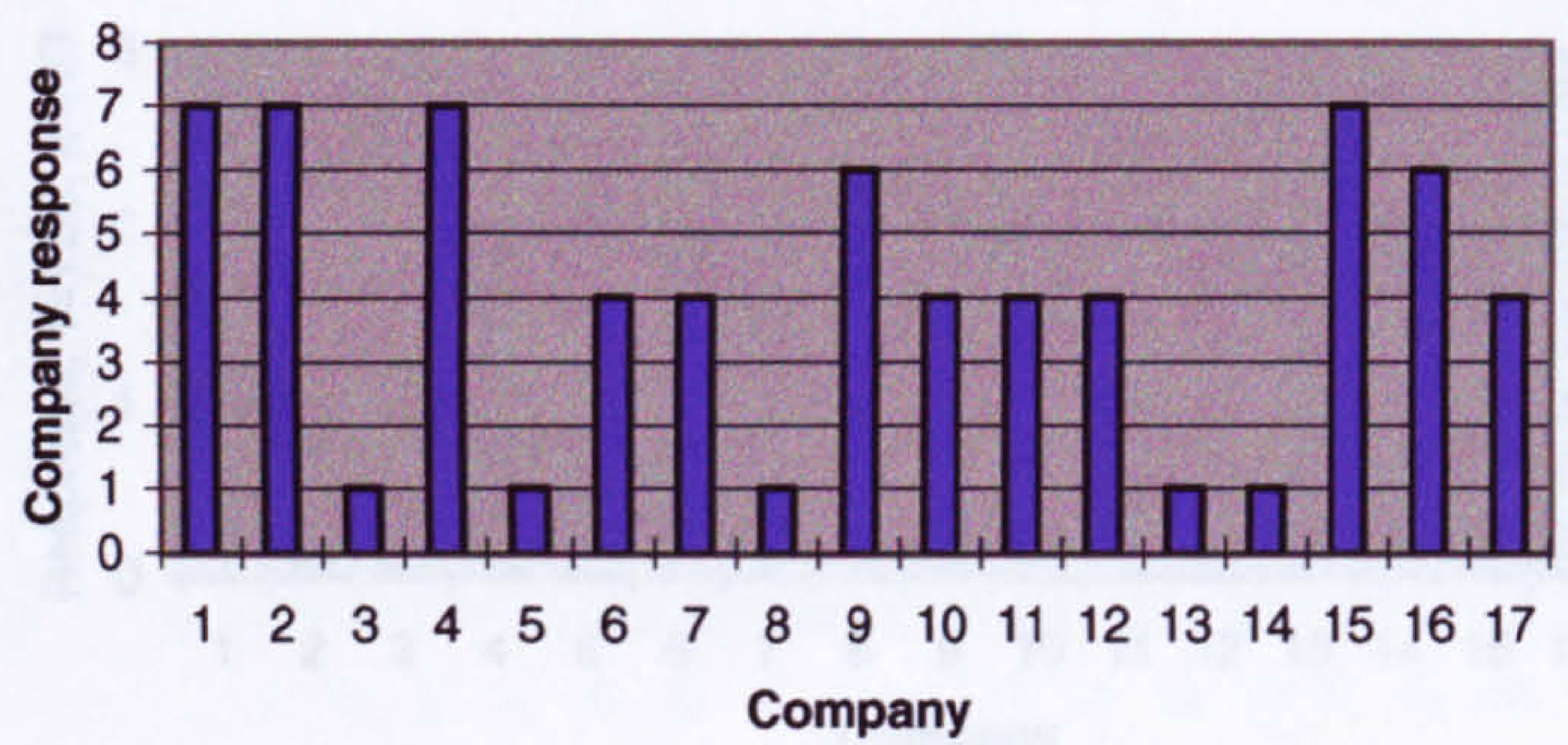
Q1. Minimum Qualification for Post



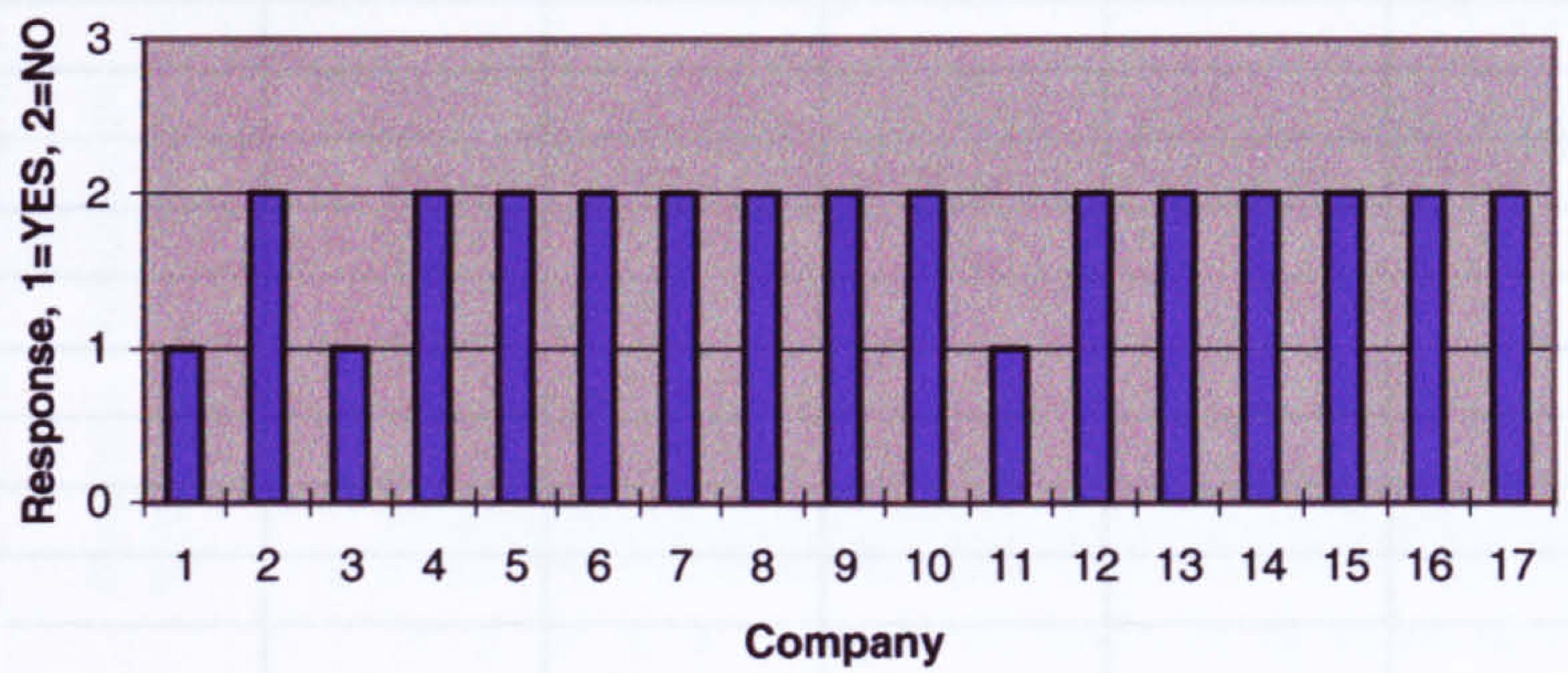
Q3. Would PhD put the company off?



Q2. Preferred Study Area



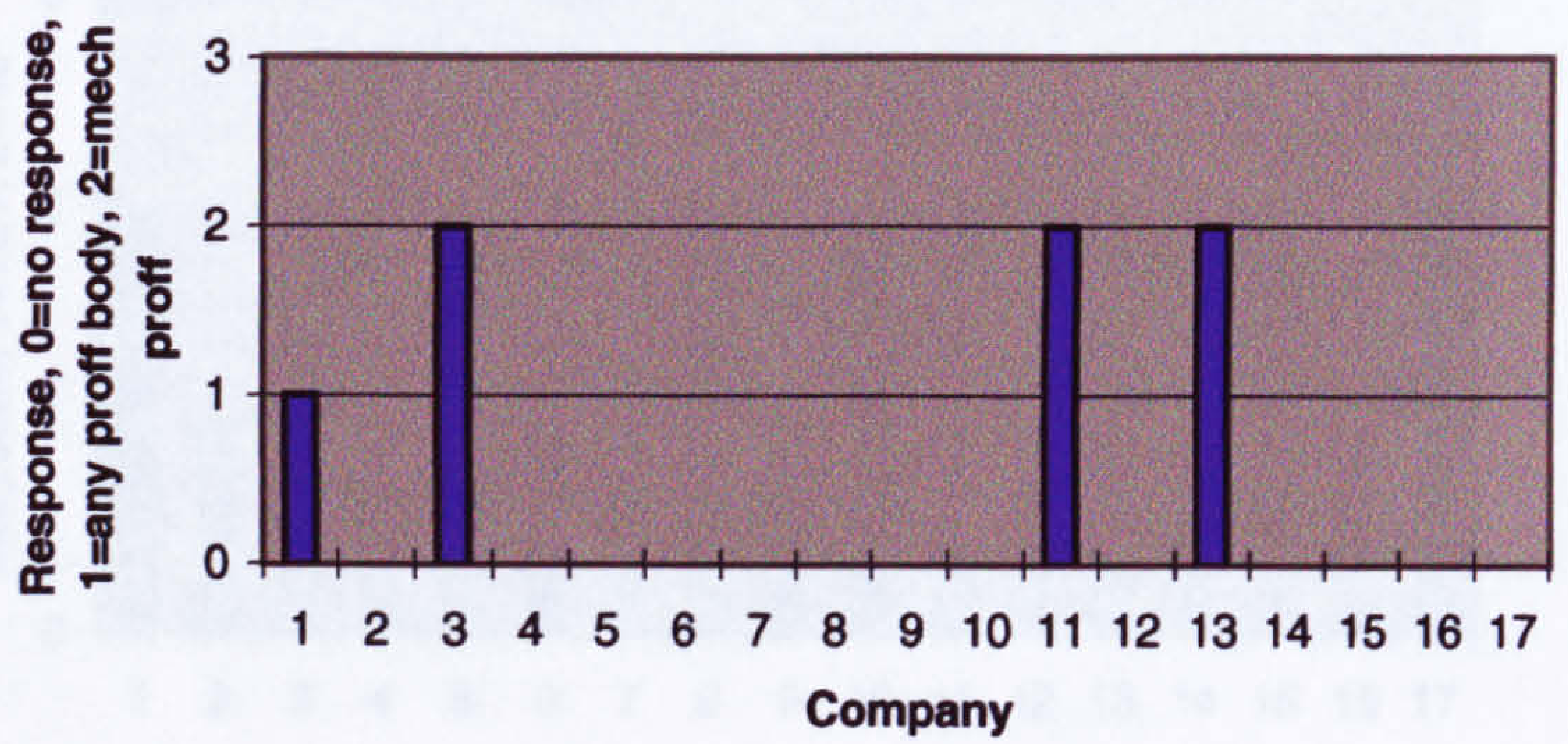
Q4. Graduate member of Professional body important?



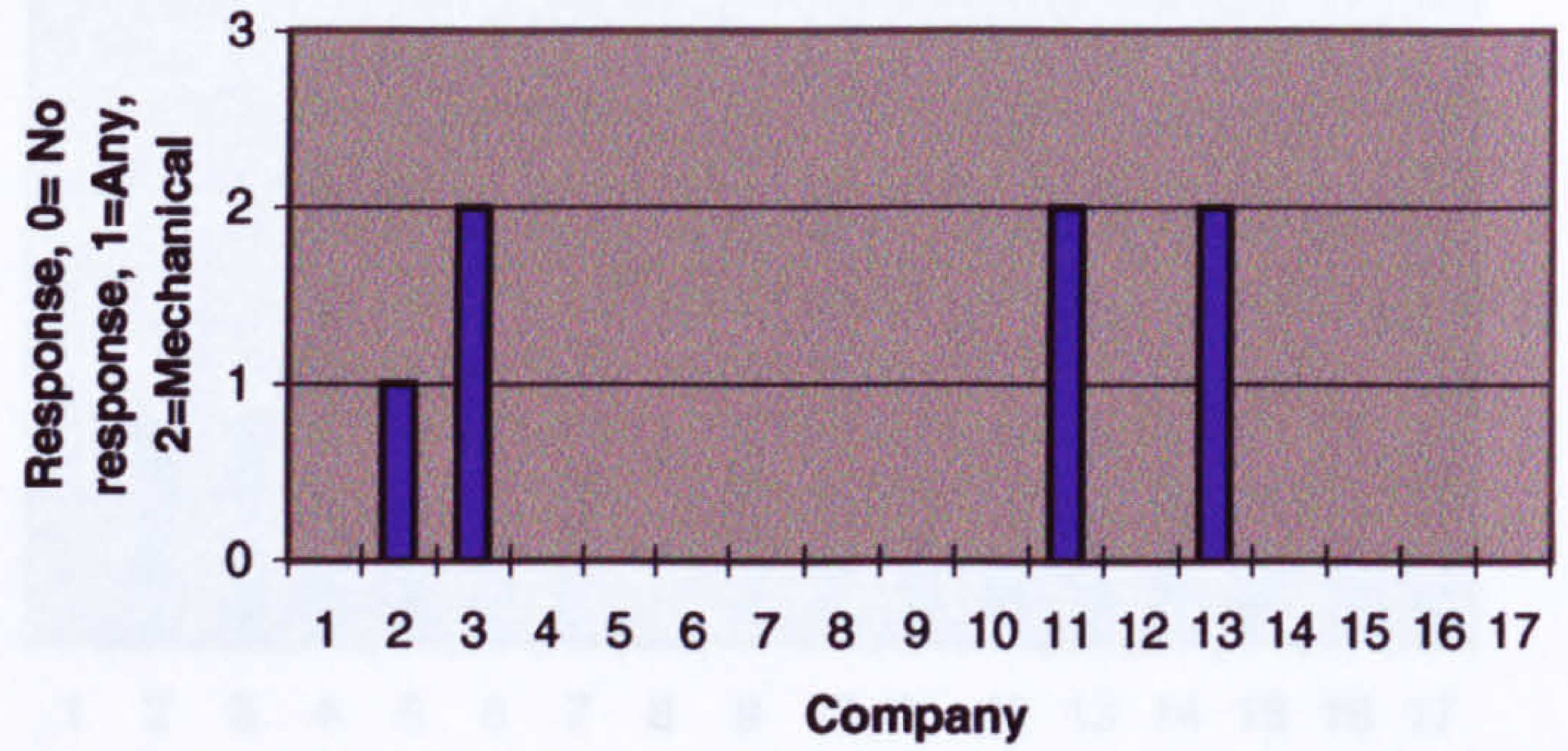
Company Responses Charts 4.1

1. Educational Background cont'd

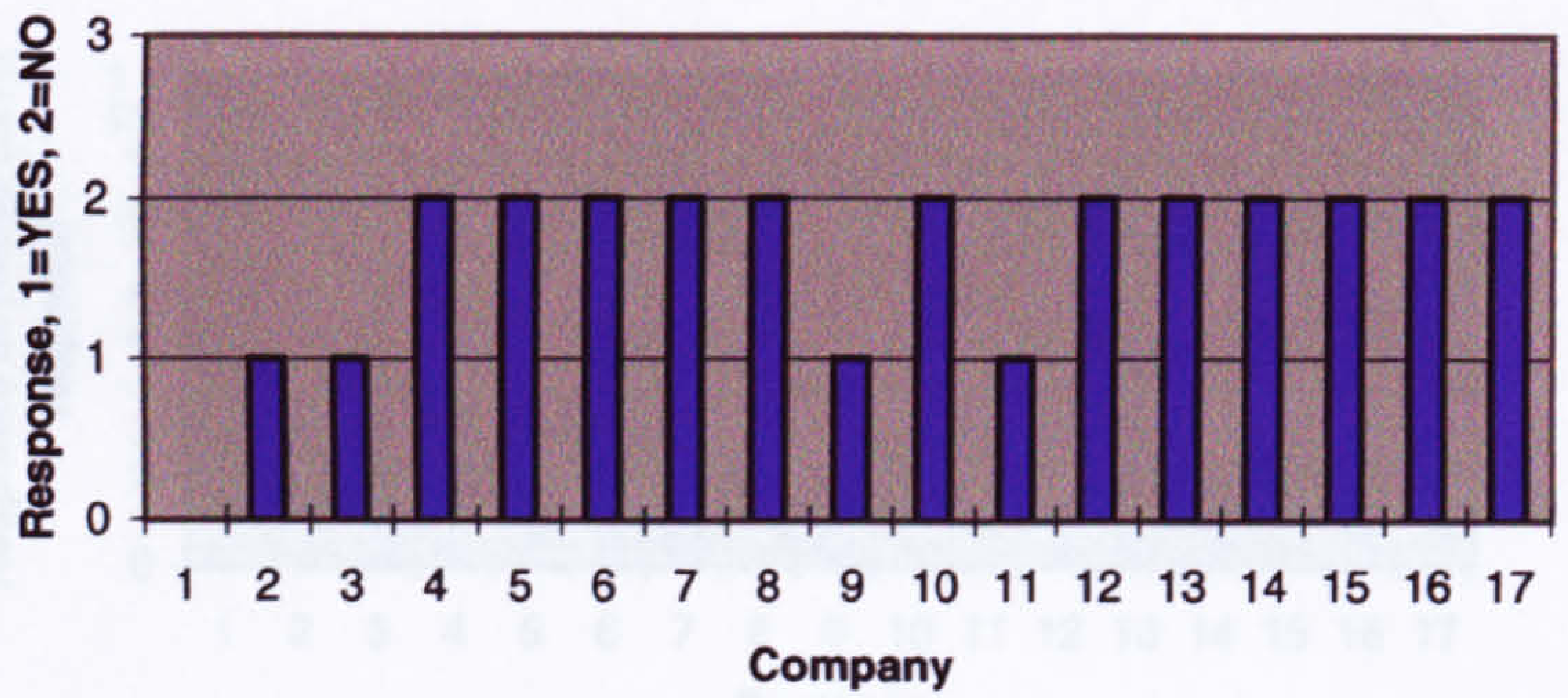
Q5. If "YES" to prior question preferred Professional body



Q7. If YES from previous question preferred Prof body

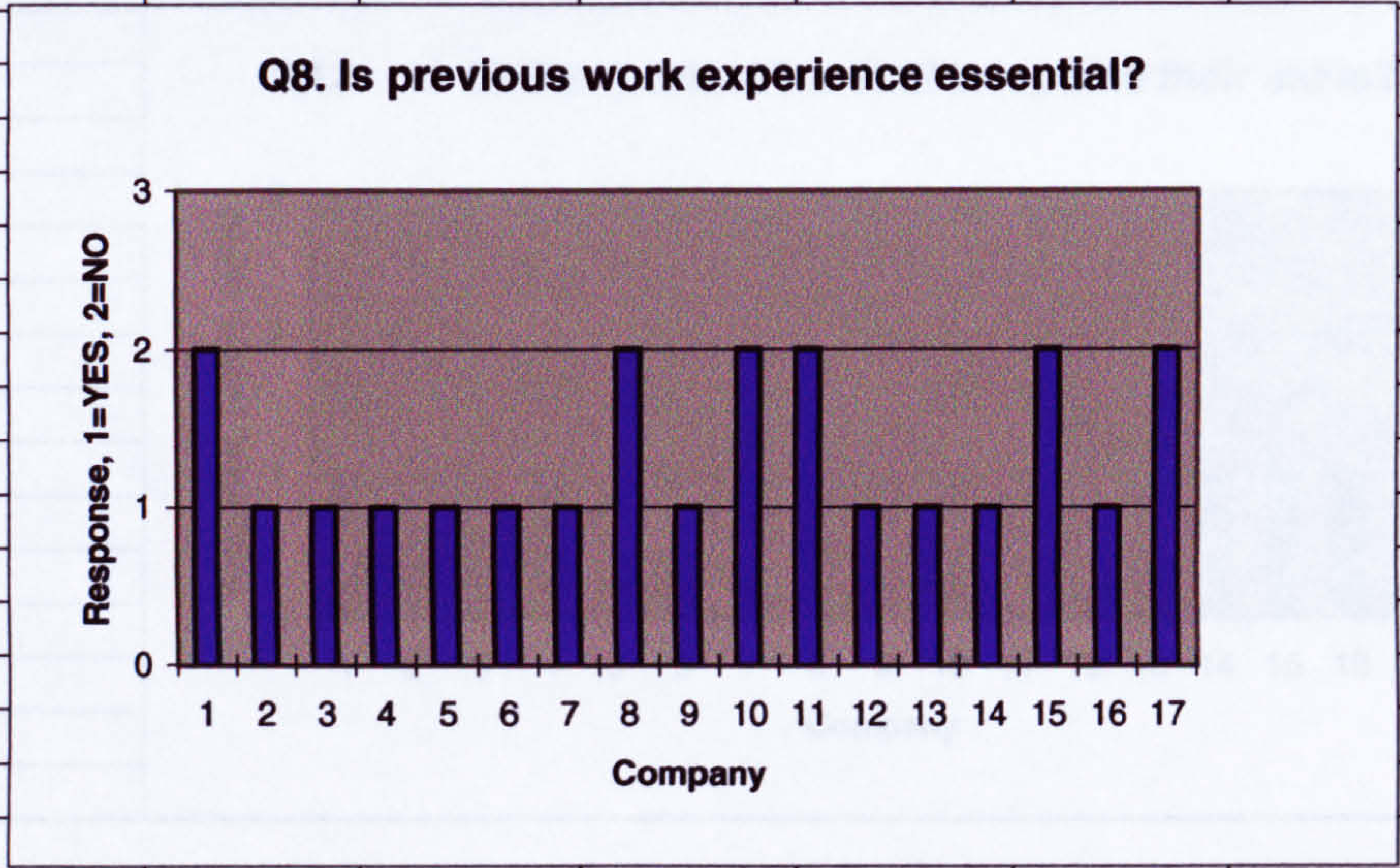


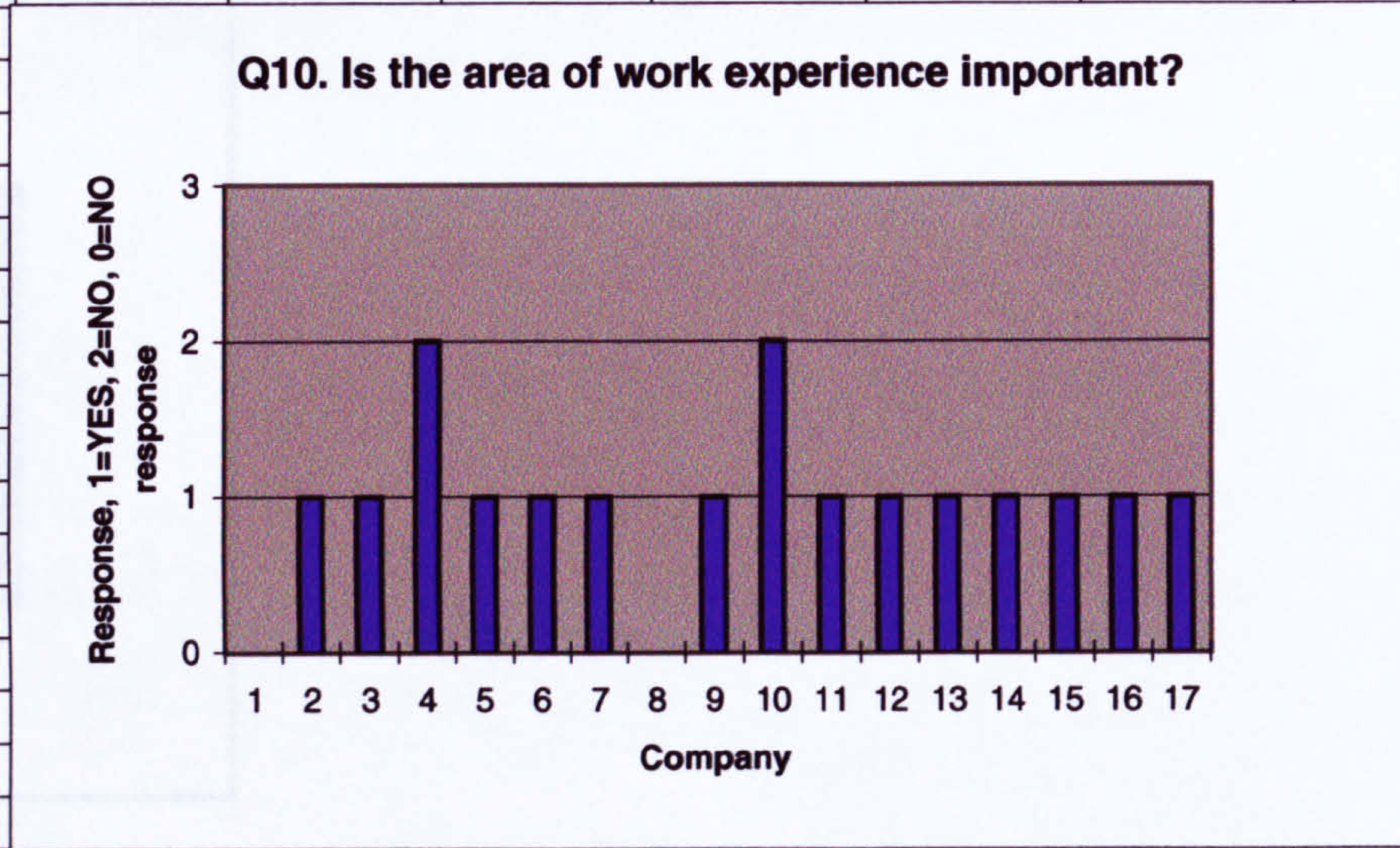
Q6. Is Chartered Engineer status important once working for company

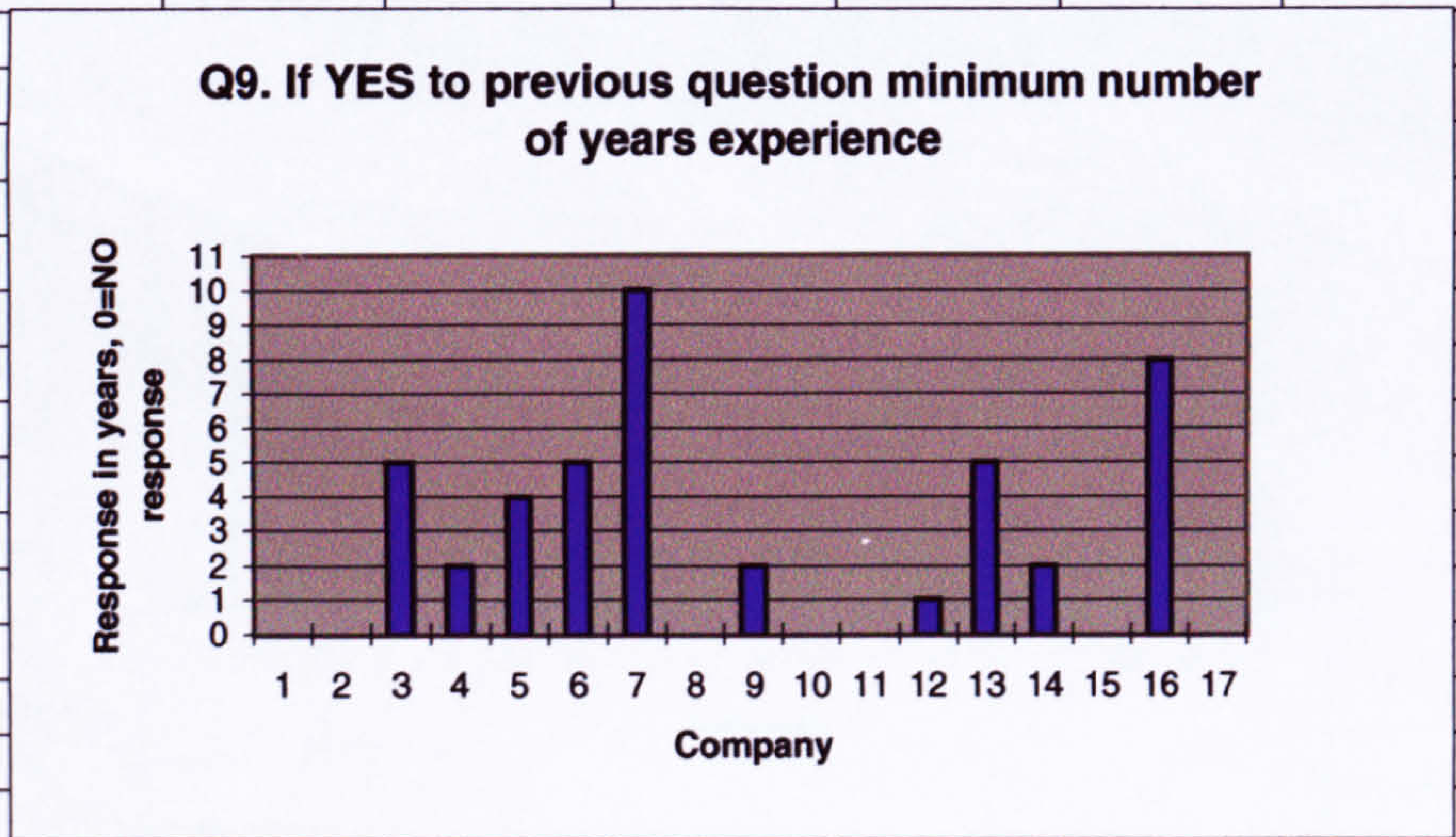


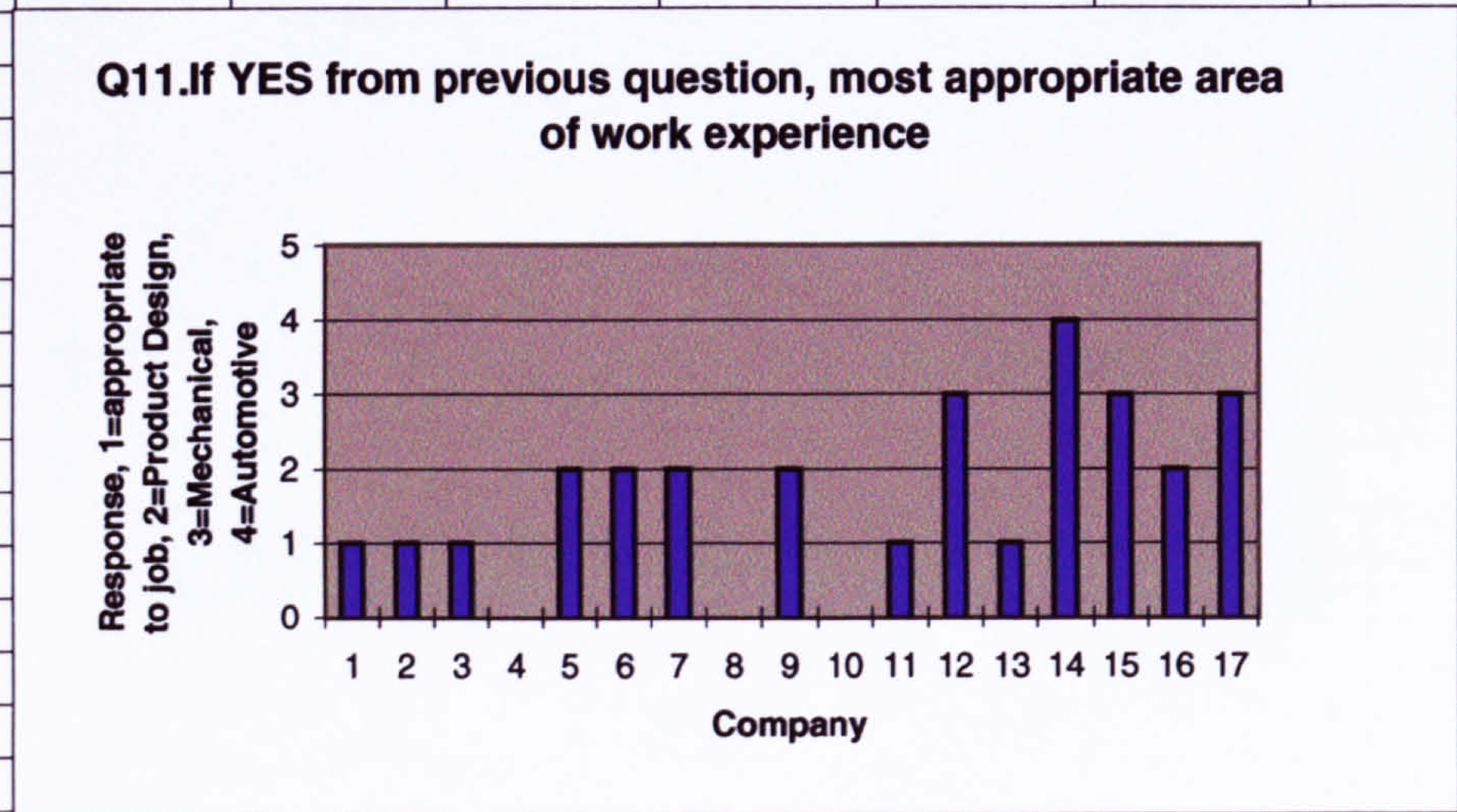
Company Responses Charts 4.2

2. Work Experience



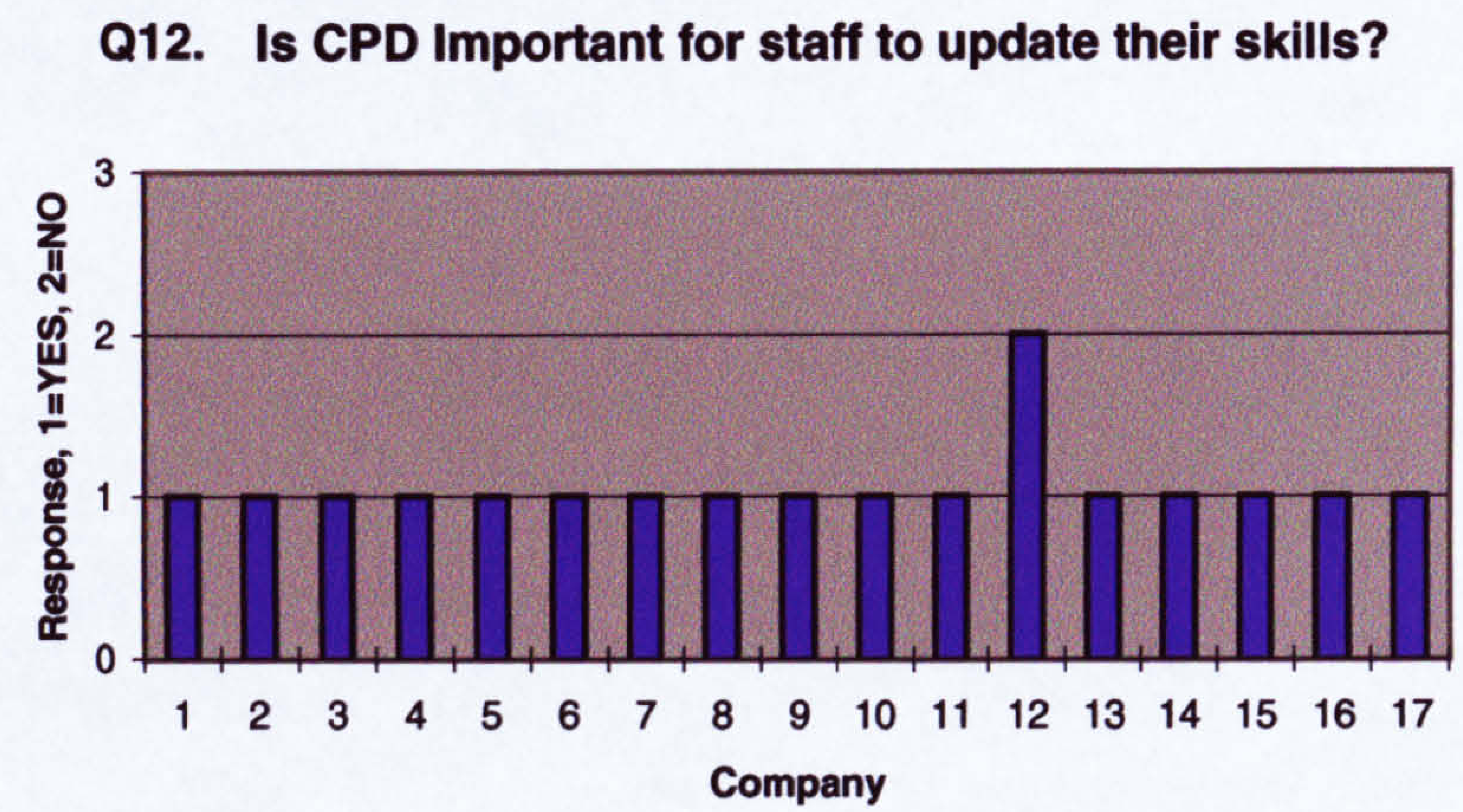






Company Responses Charts 4.3

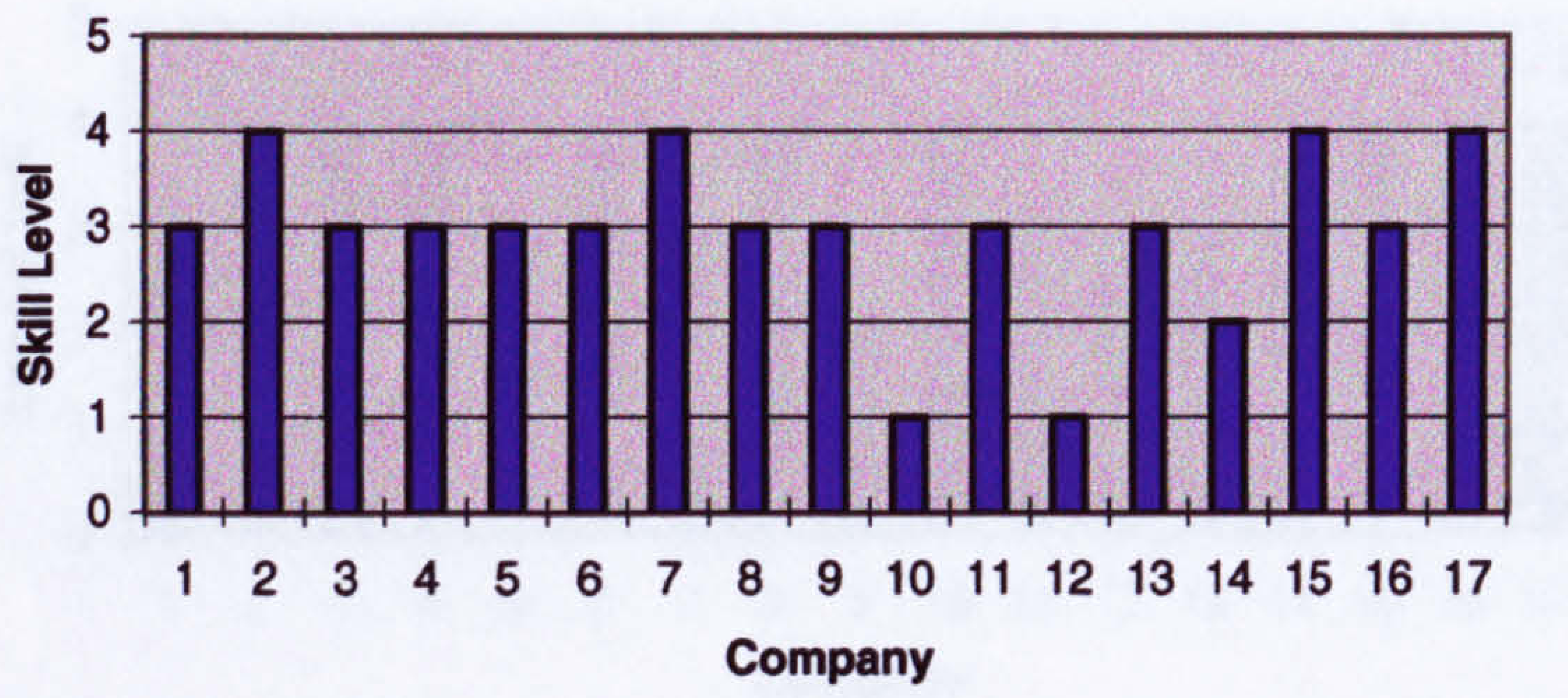
2. Work Experience cont'd



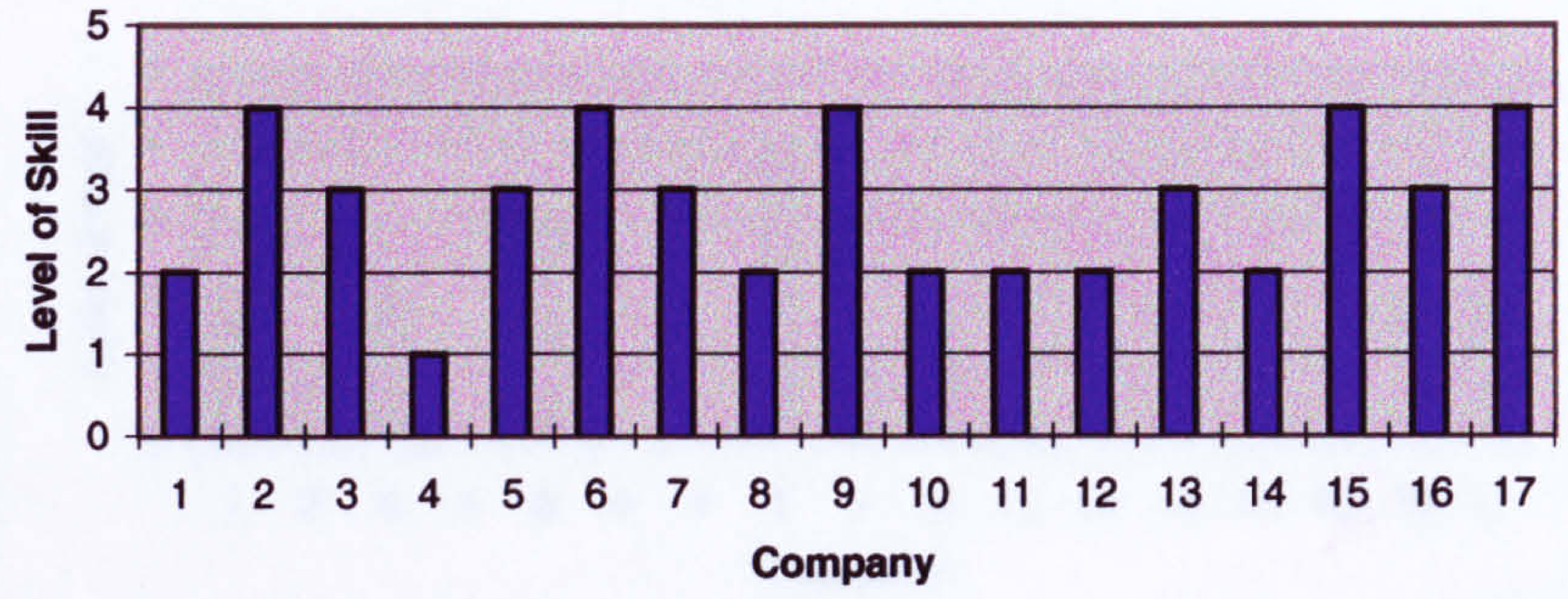
Company Responses Charts 4.4

3. Manual Drawing Board Ability and Communication skills

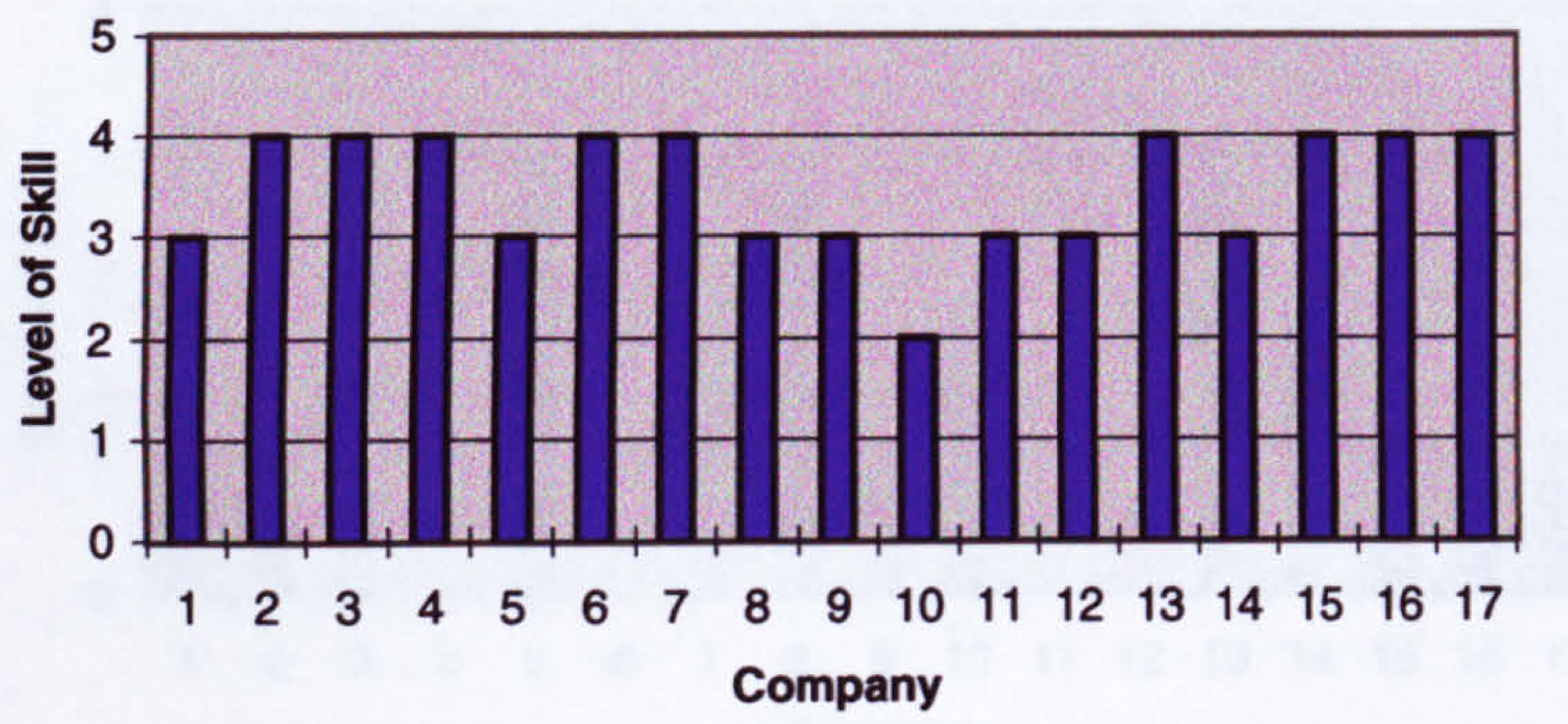
Q13. Produce Design Sketches / Diagrams



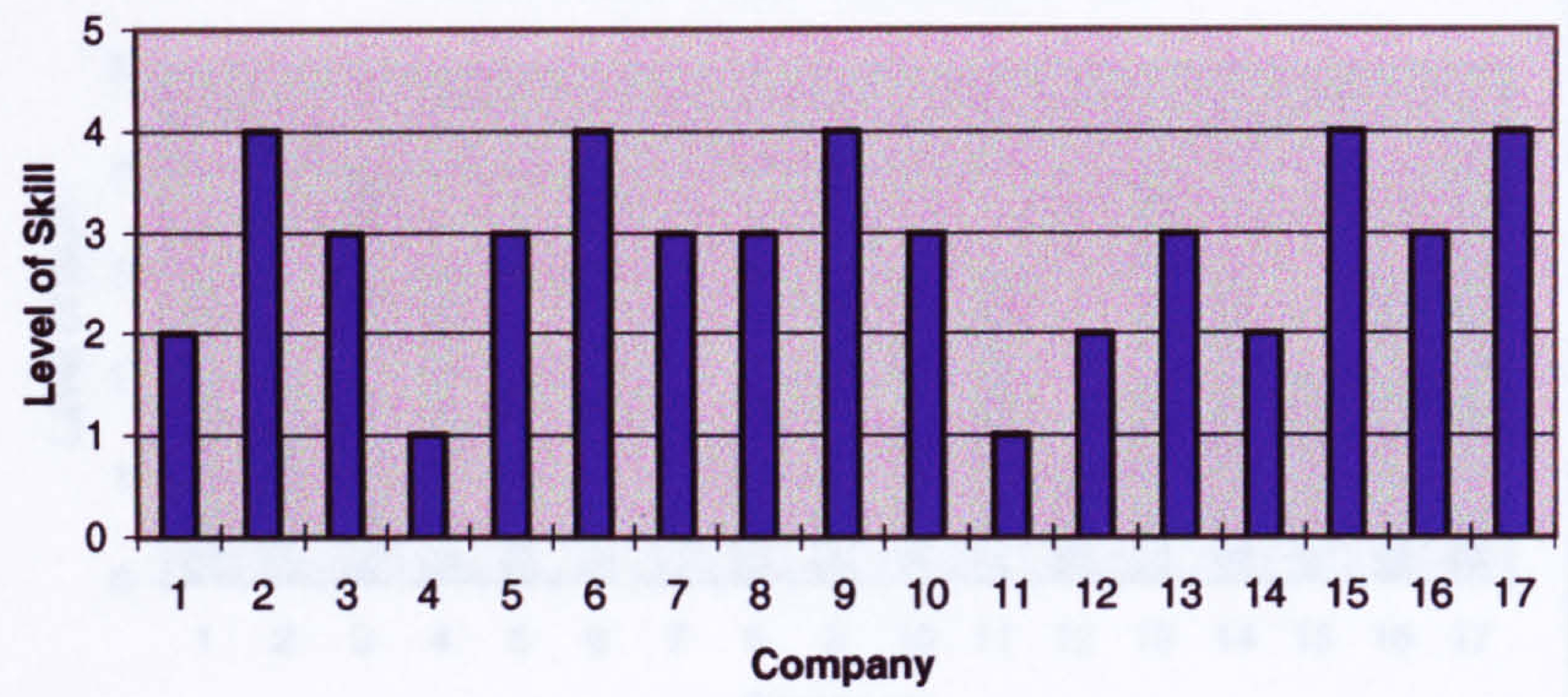
Q15. Produce Part Drawings



Q14. Read and Interpret Engineering Drawings

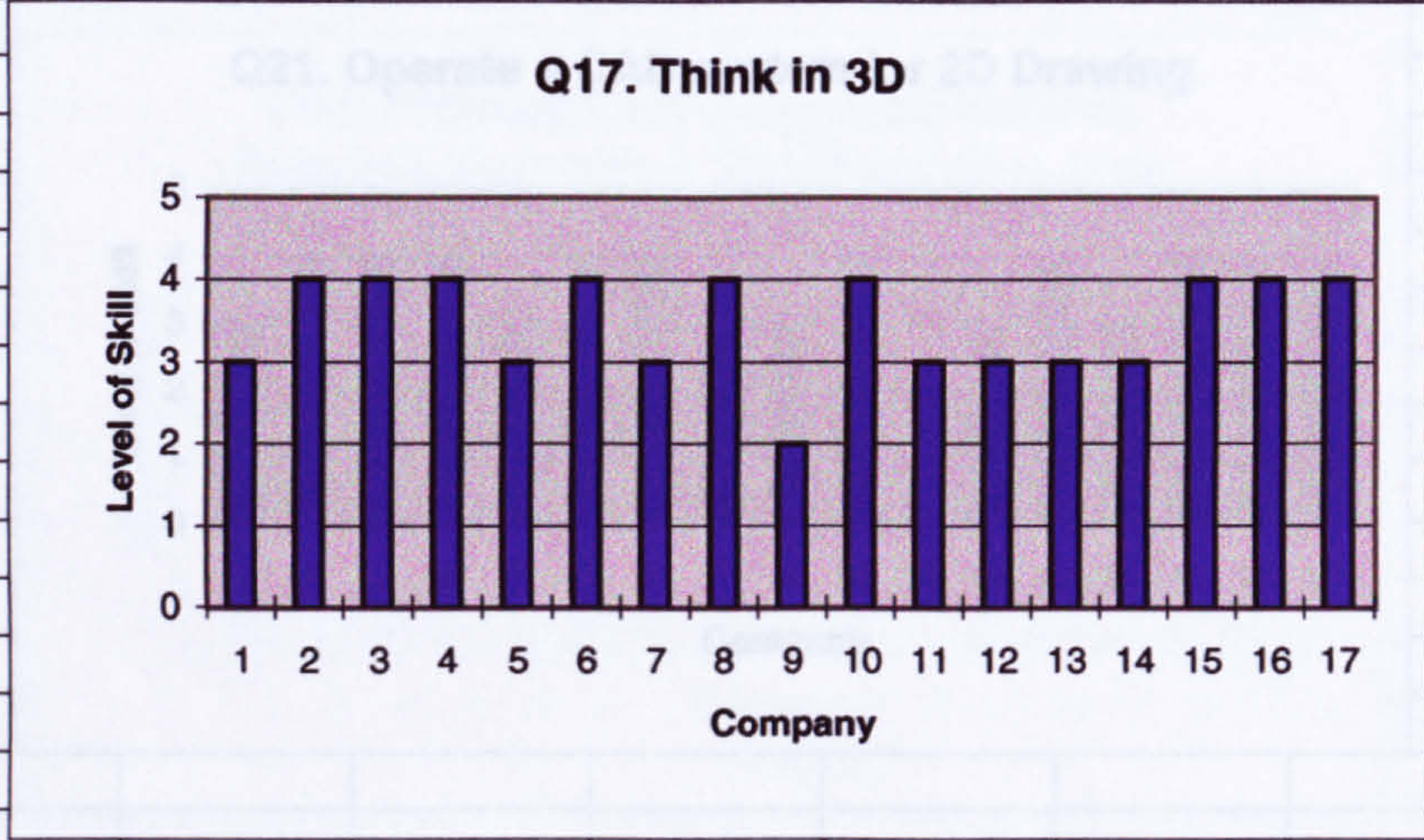


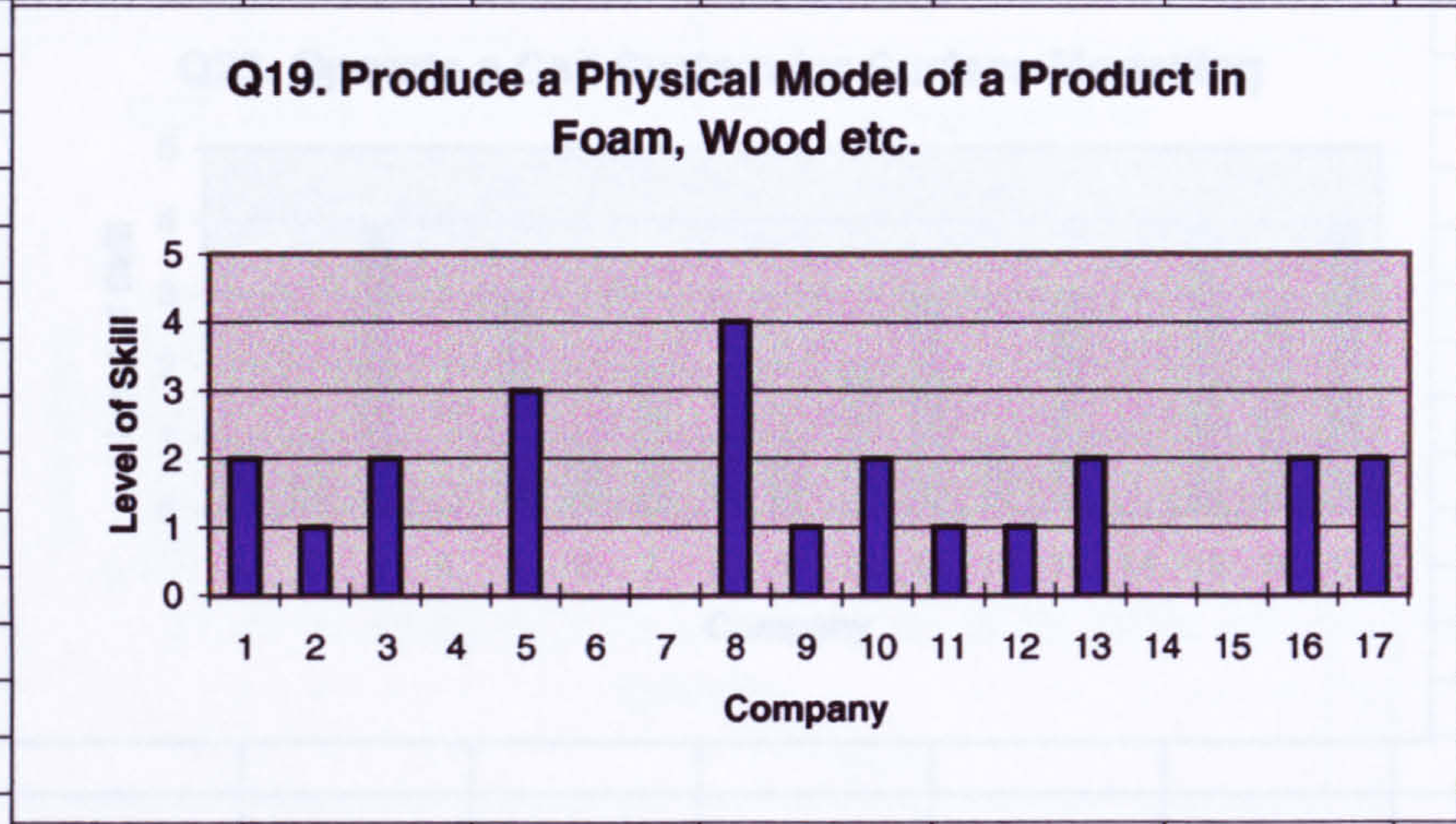
Q16. Produce Detail Drawings

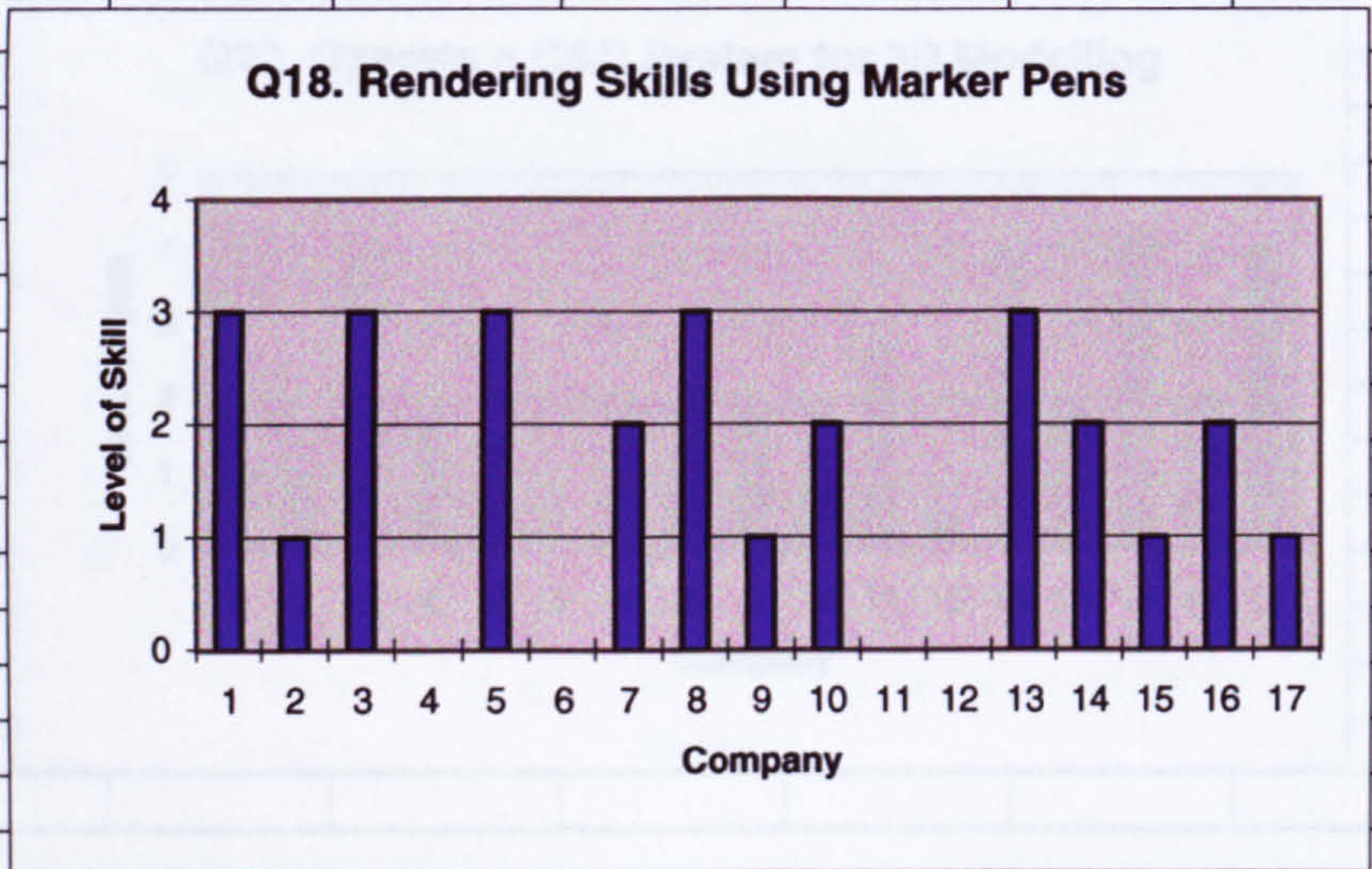


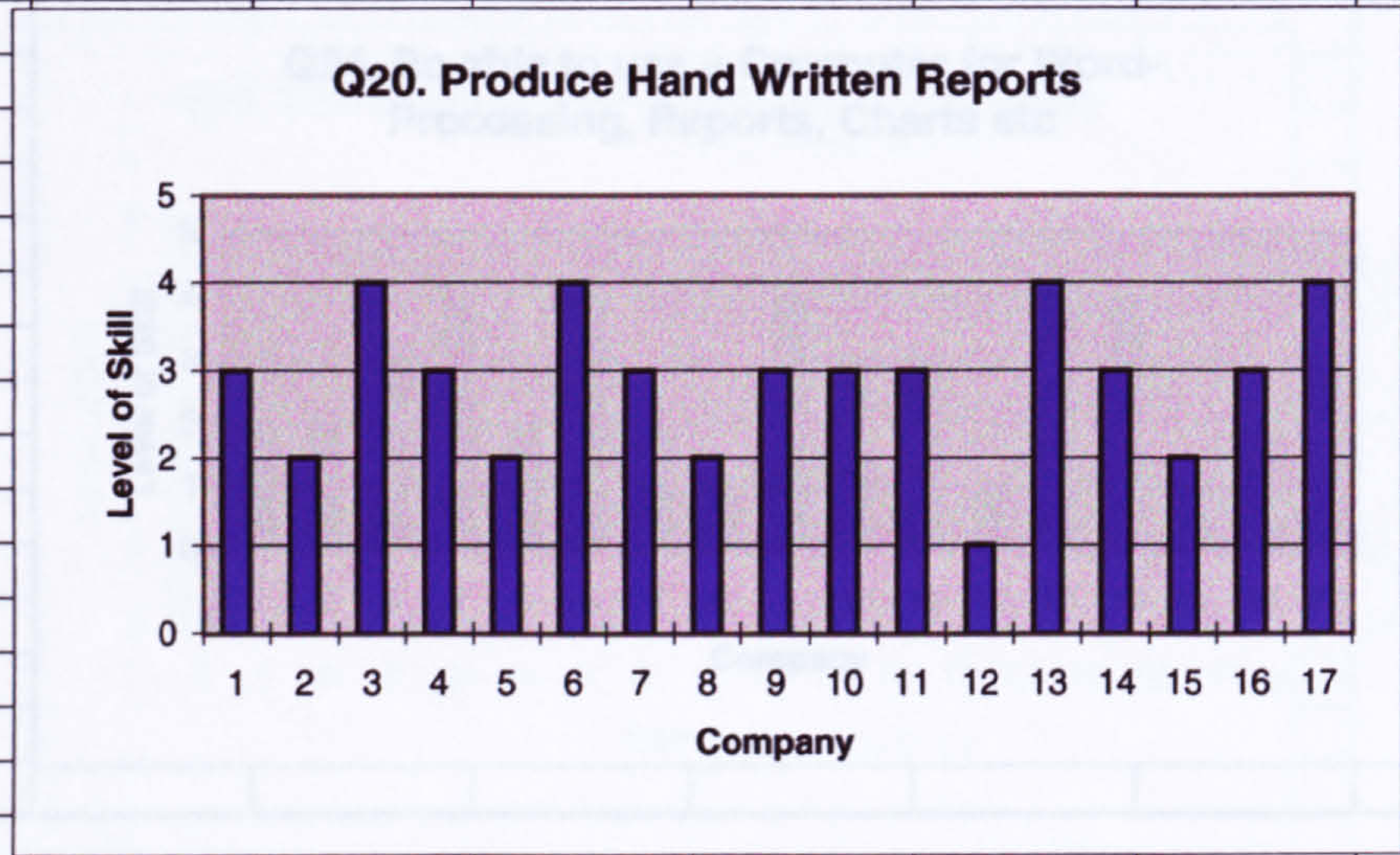
Company Responses Charts 4.5

3. Manual Drawing Board ability and Communication Skills cont'd



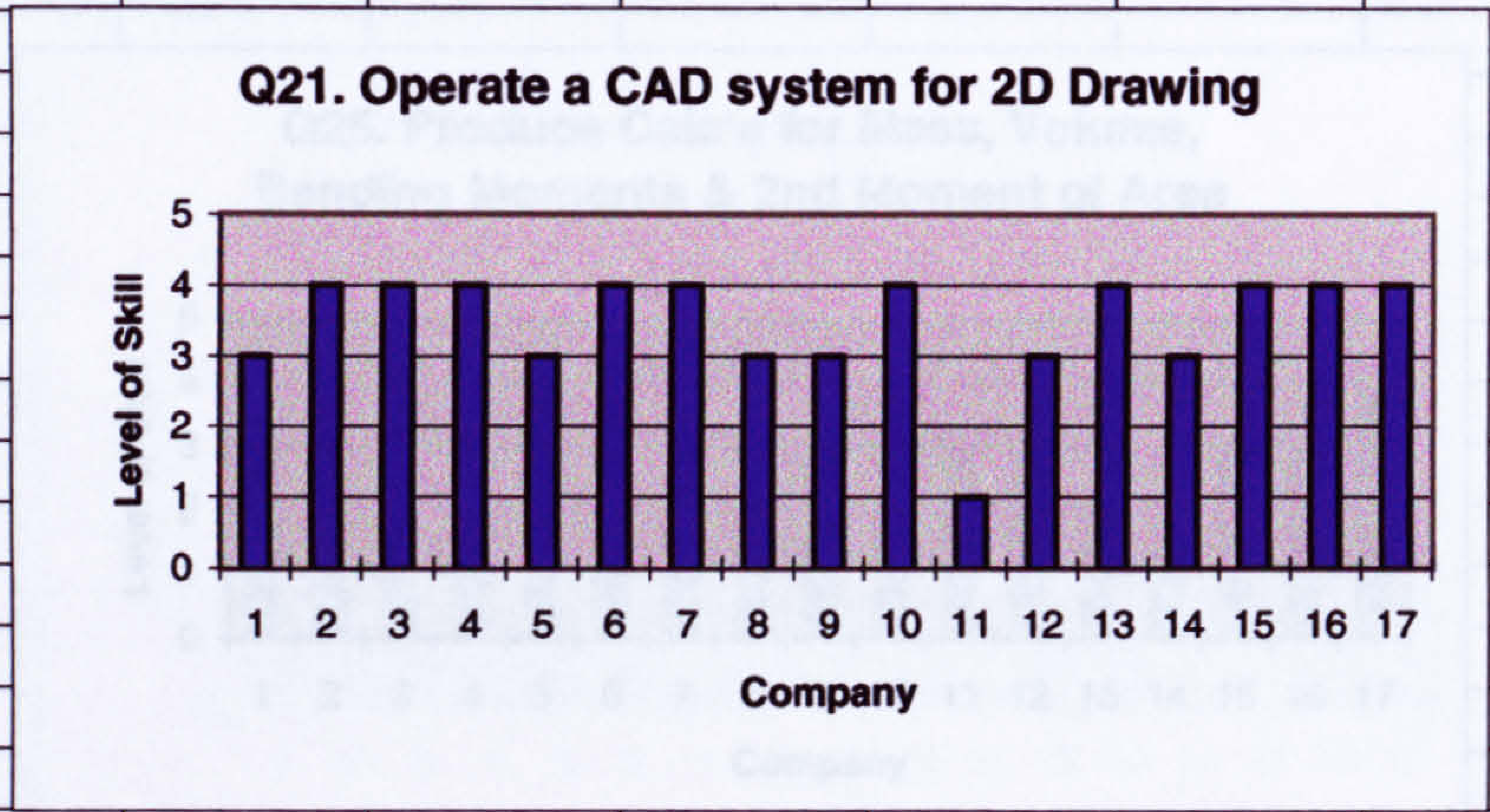


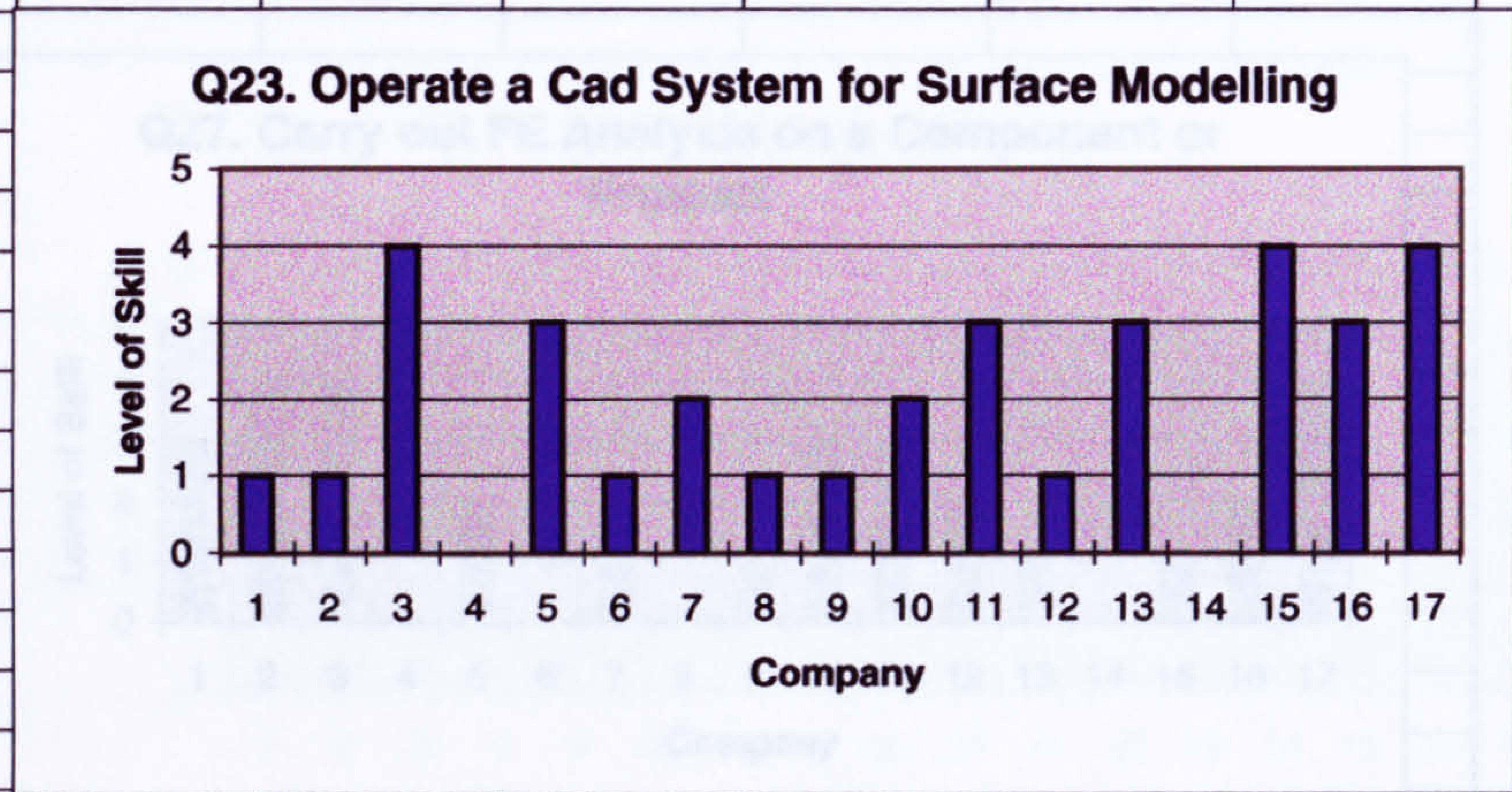


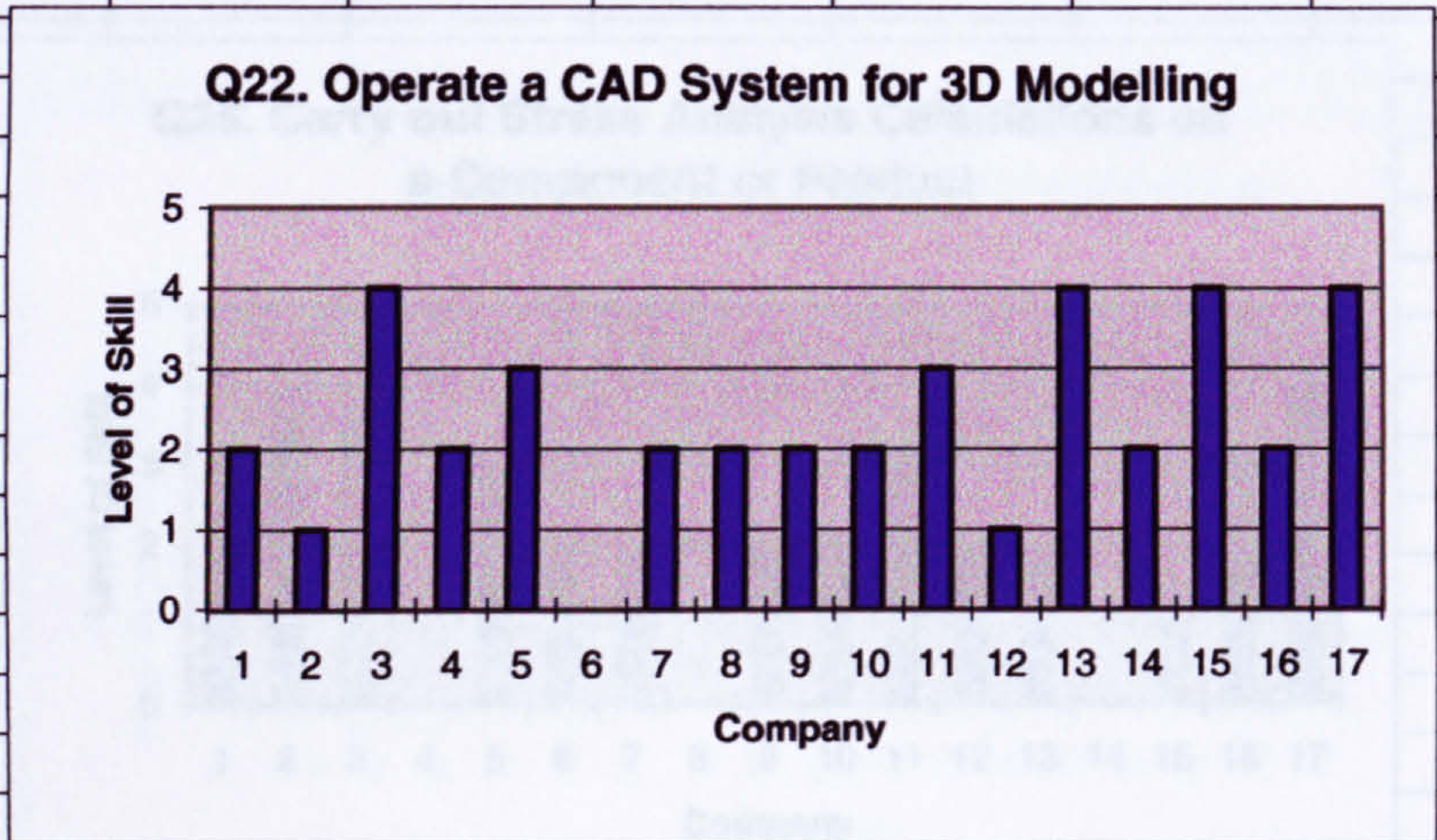


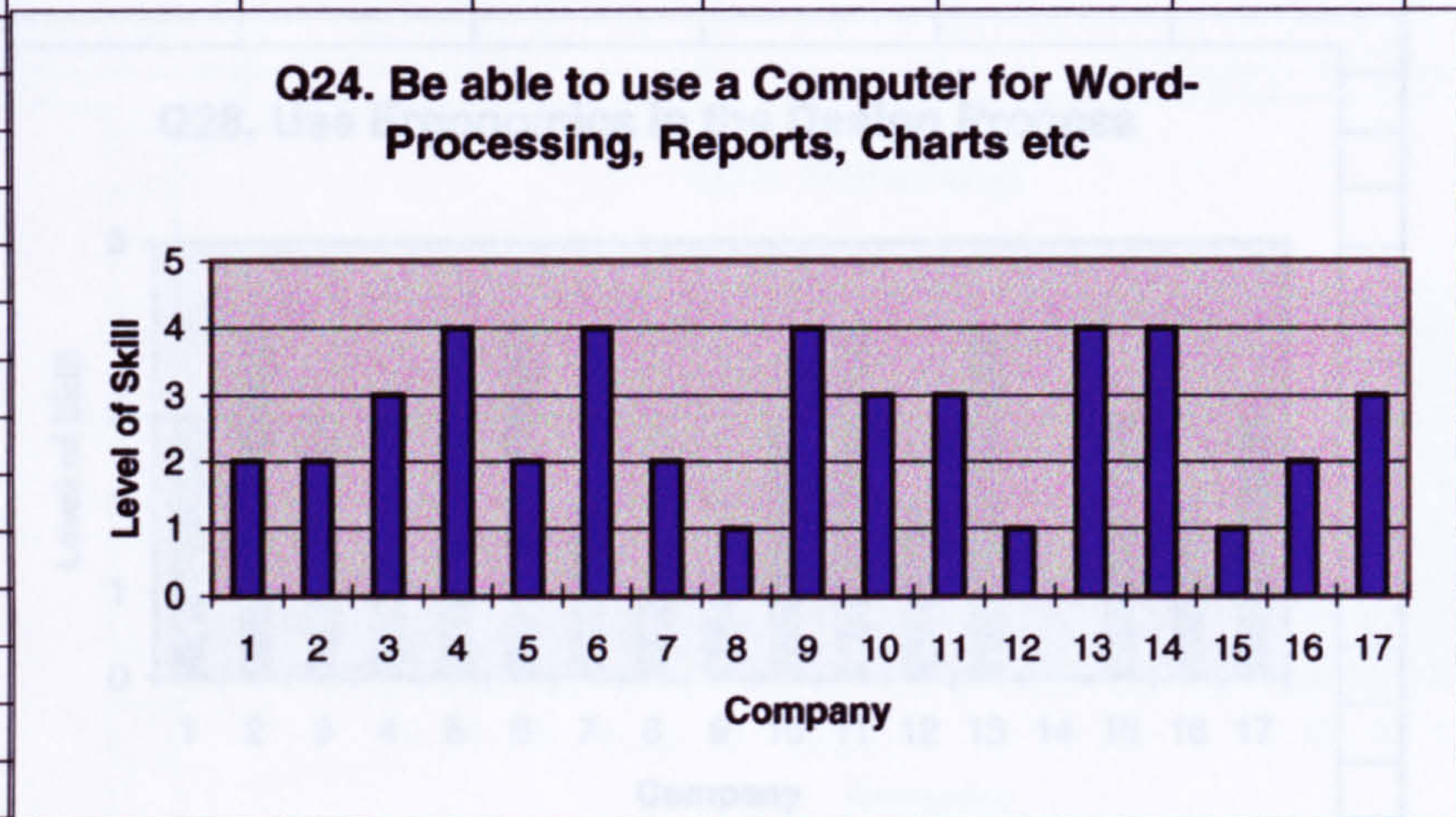
Company Responses Charts 4.6

4. Use of Computers in Design





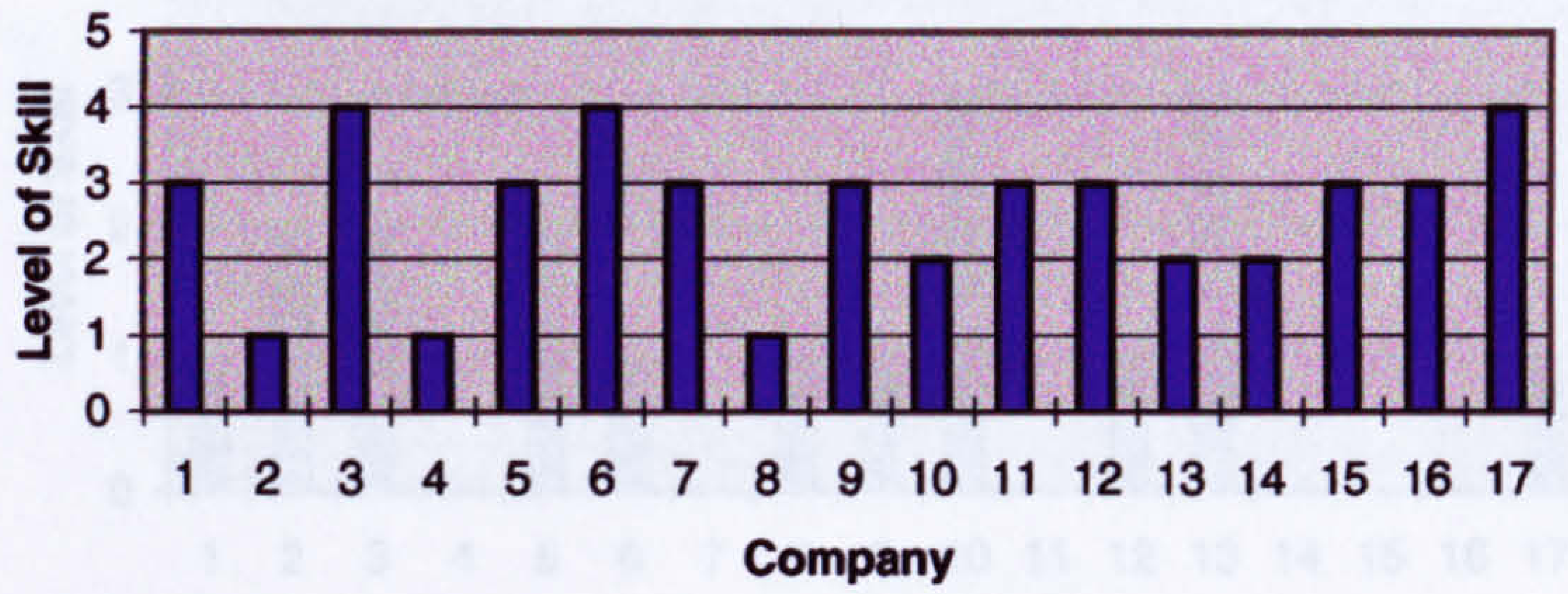




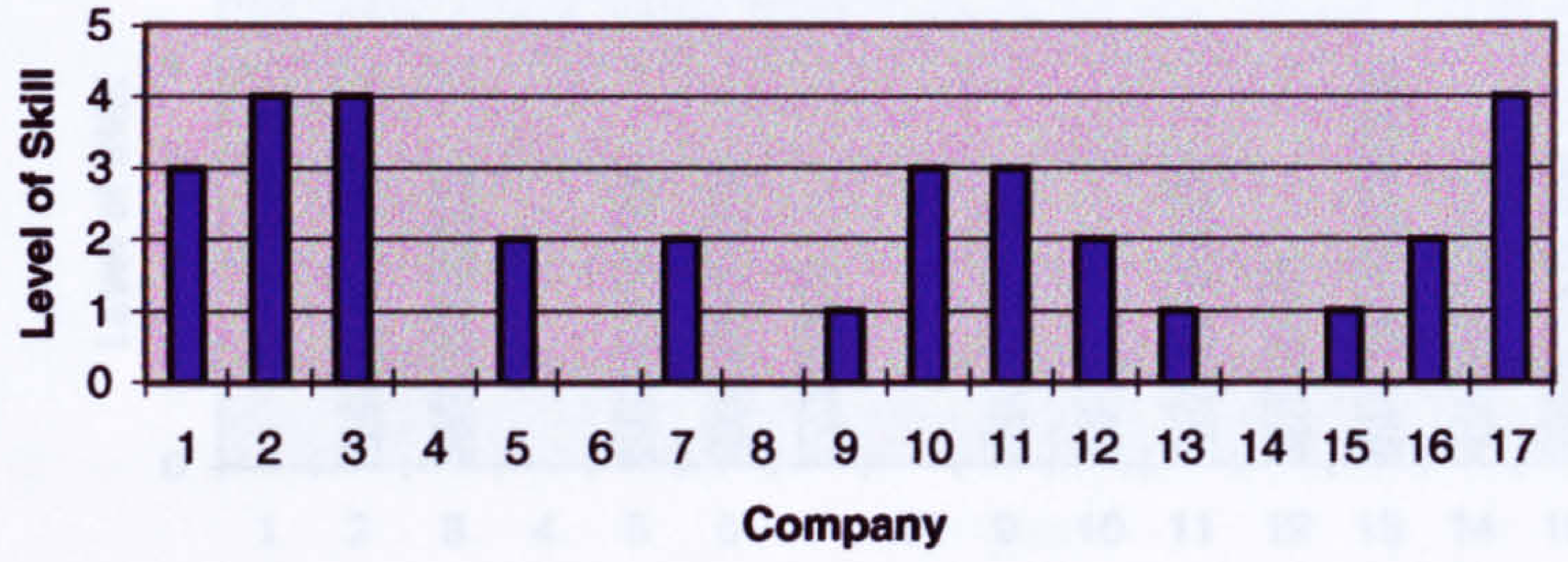
Company Responses Charts 4.7

5. Analysis of Design

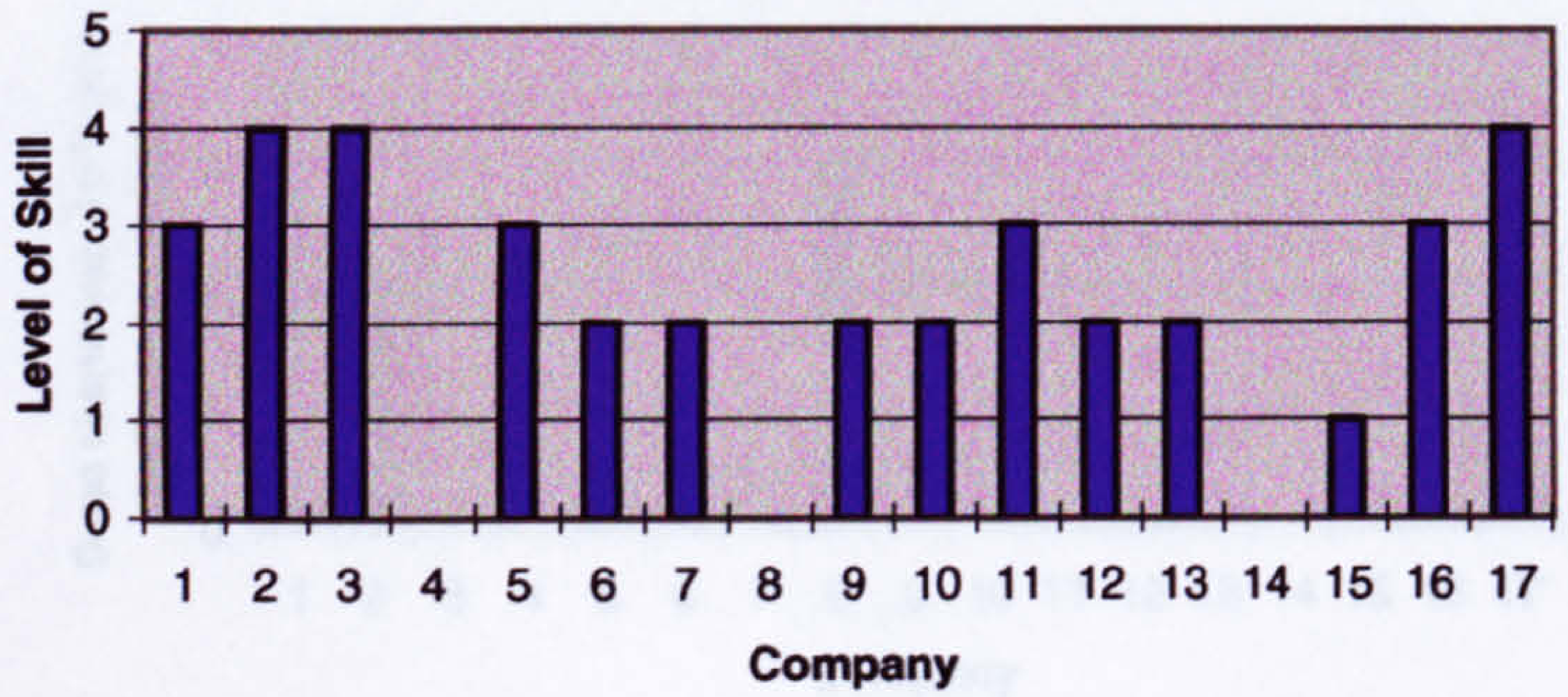
Q25. Produce Calc's for Mass, Volume, Bending Moments & 2nd Moment of Area



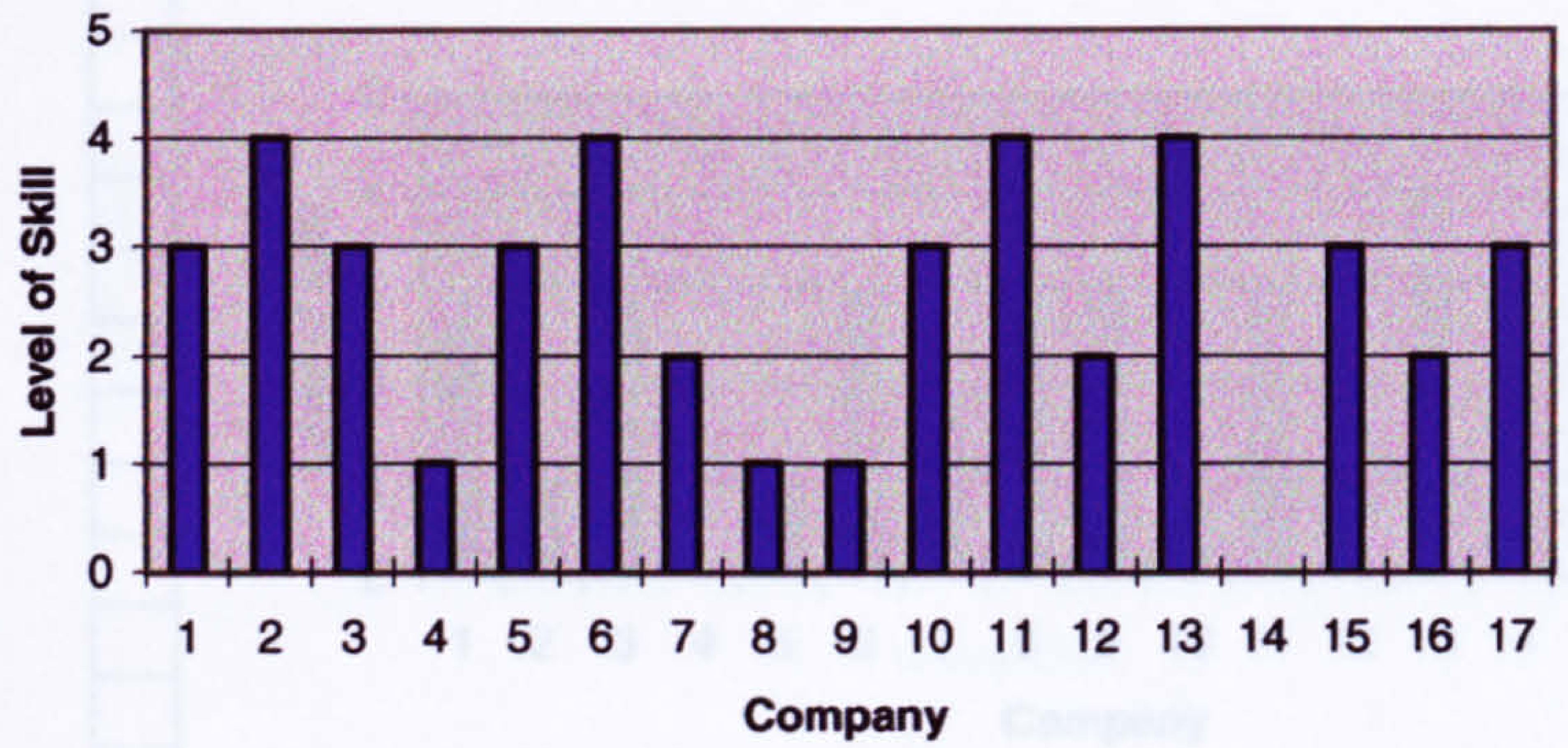
Q27. Carry out FE Analysis on a Component or Product



Q26. Carry out Stress Analysis Calculations on a Component or Product

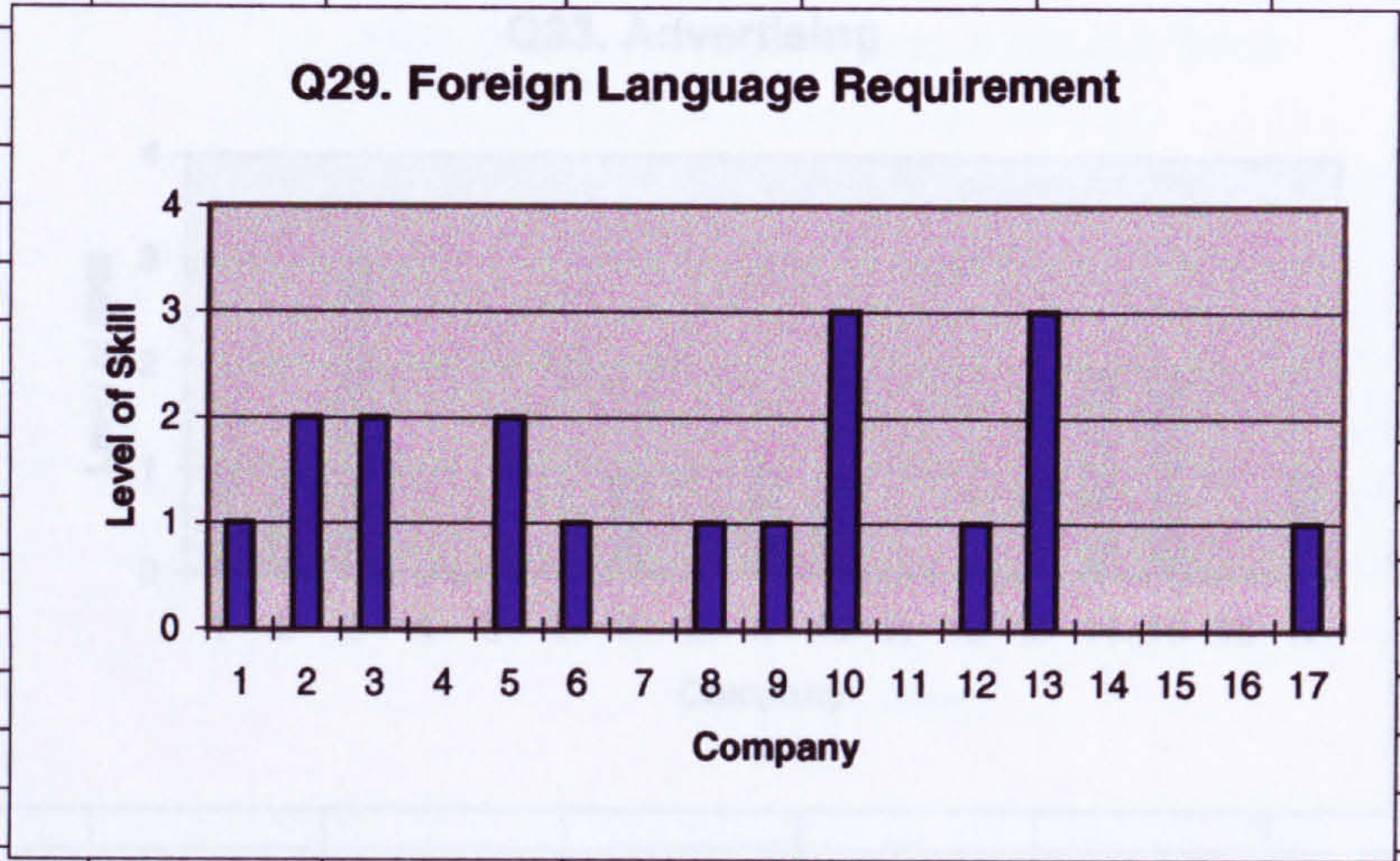


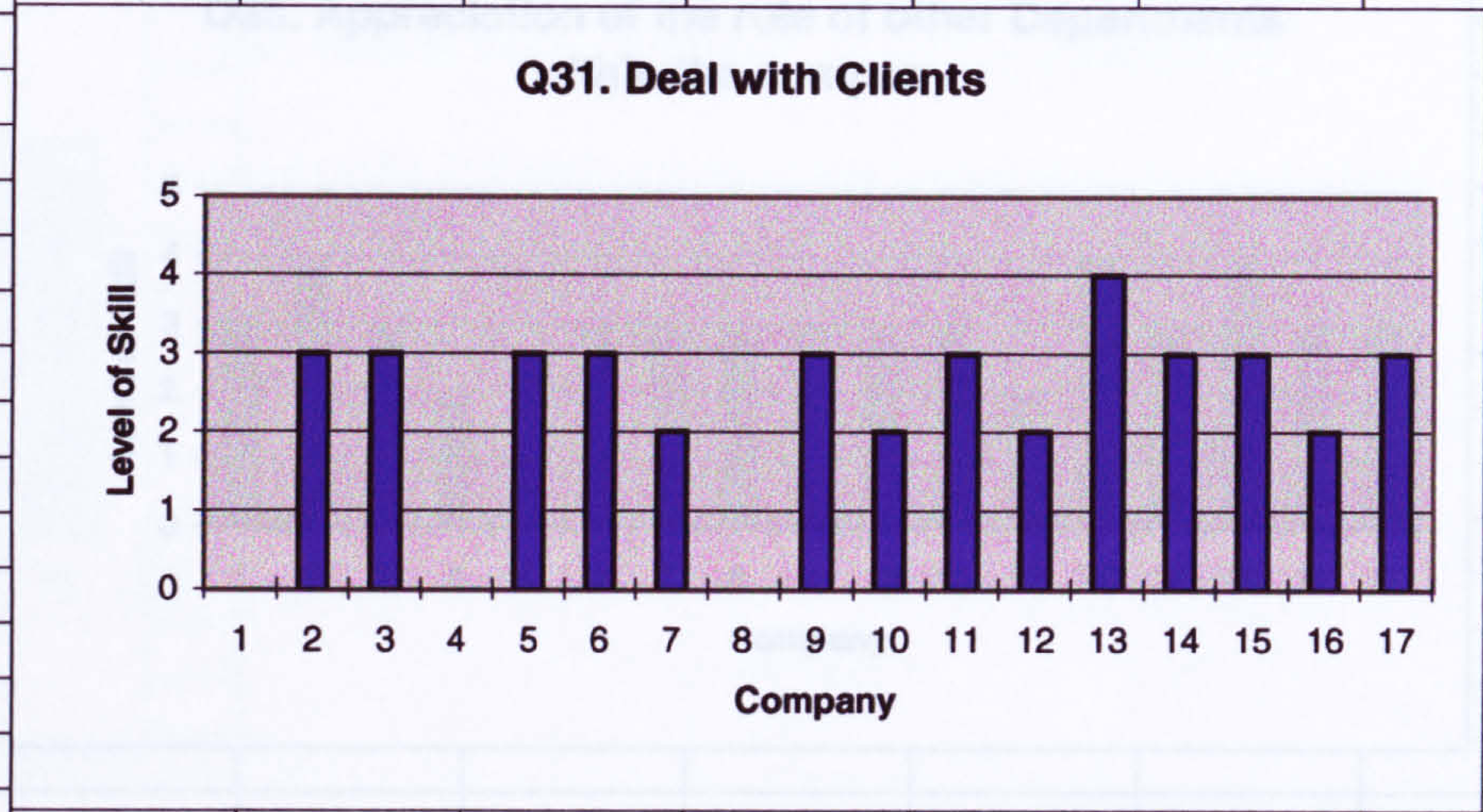
Q28. Use Ergonomics in the Design Process

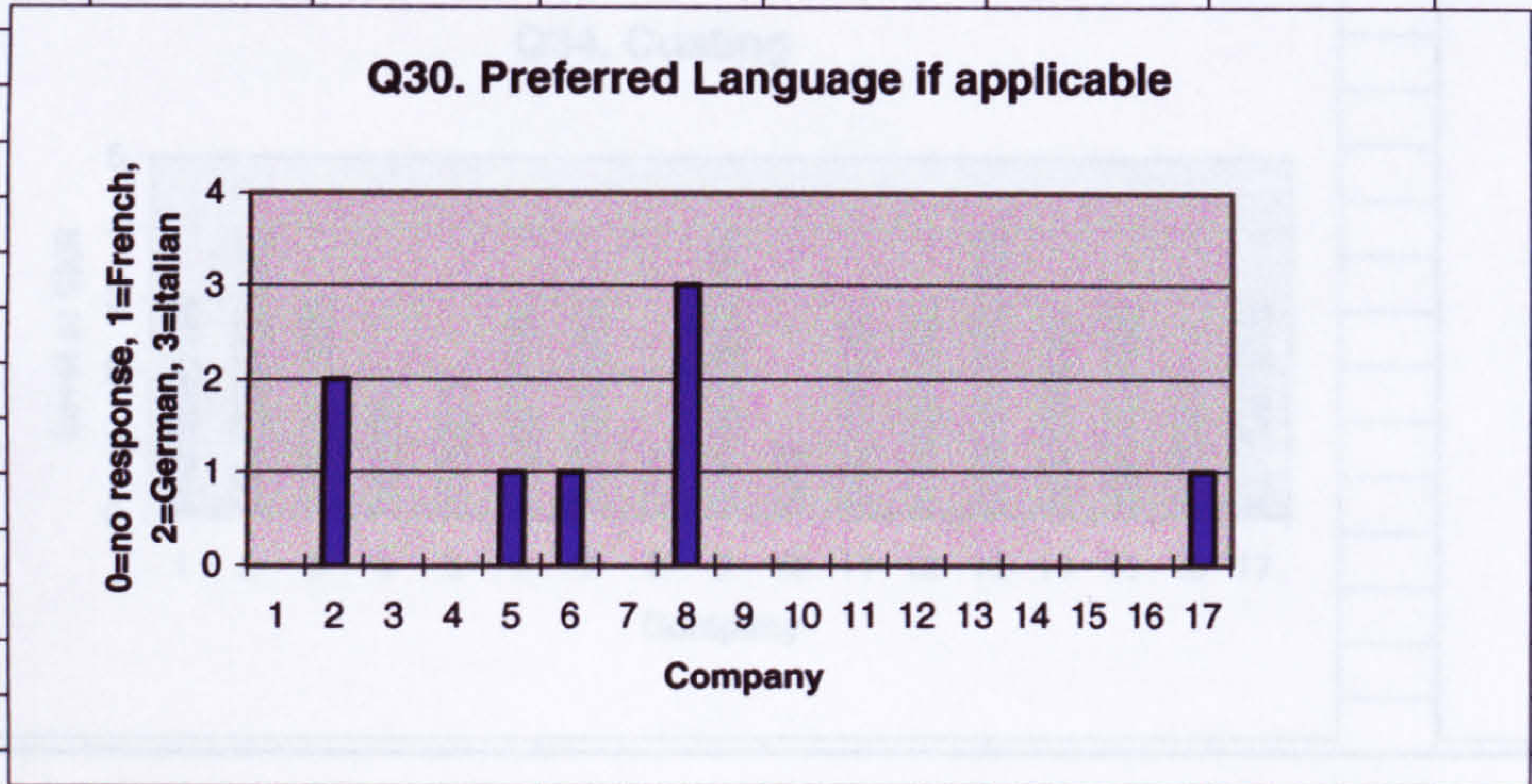


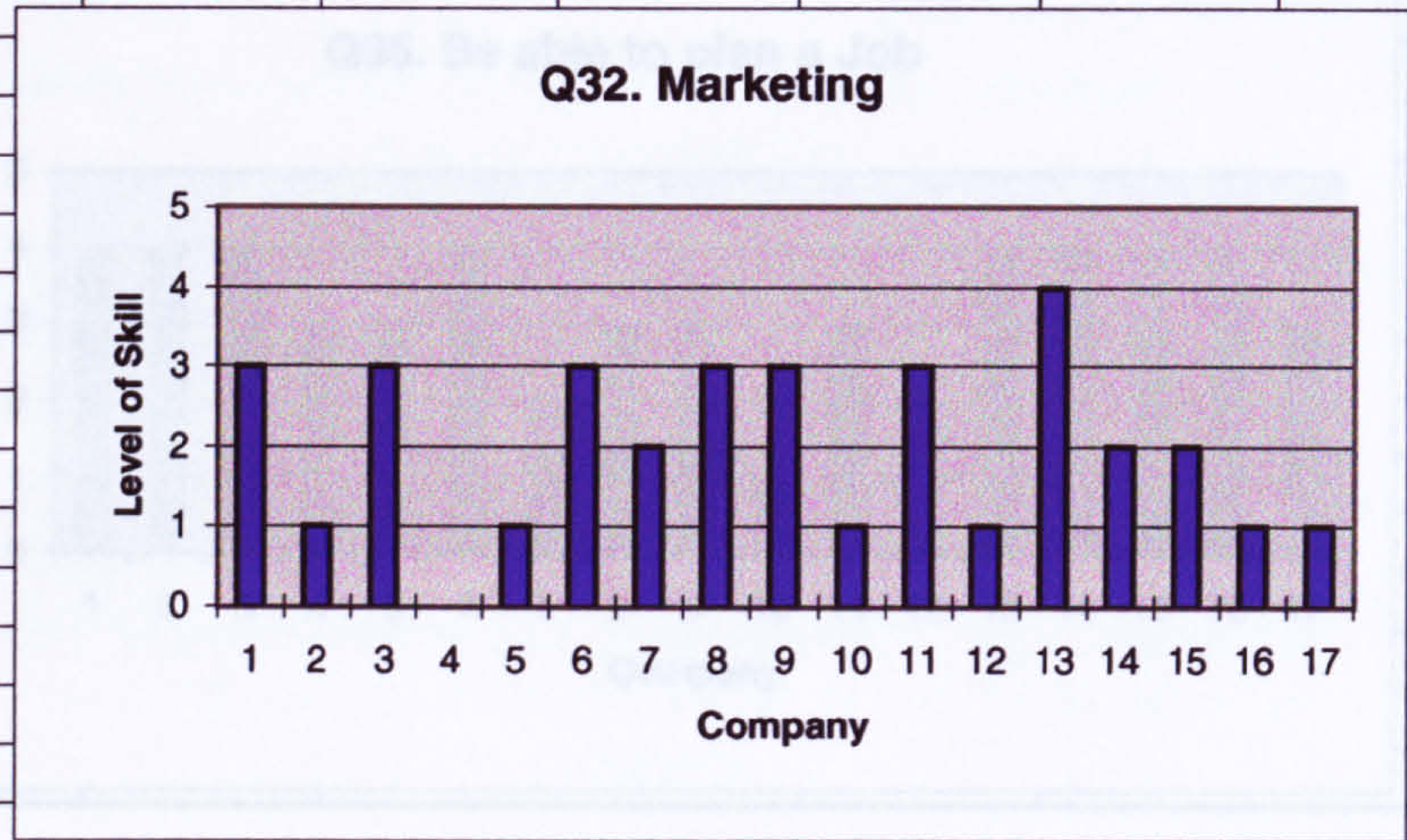
Company Responses Charts 4.8

6. Business



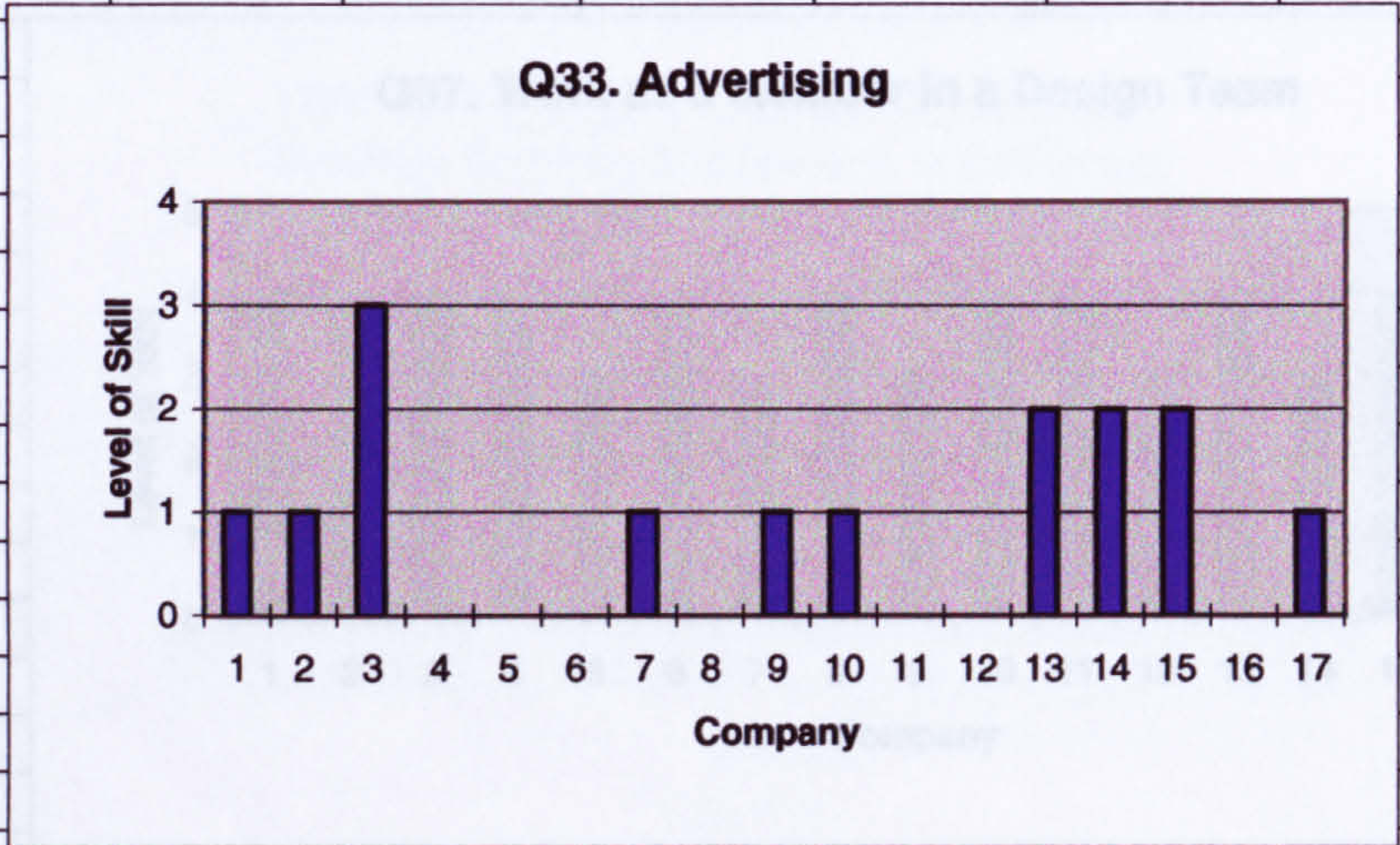


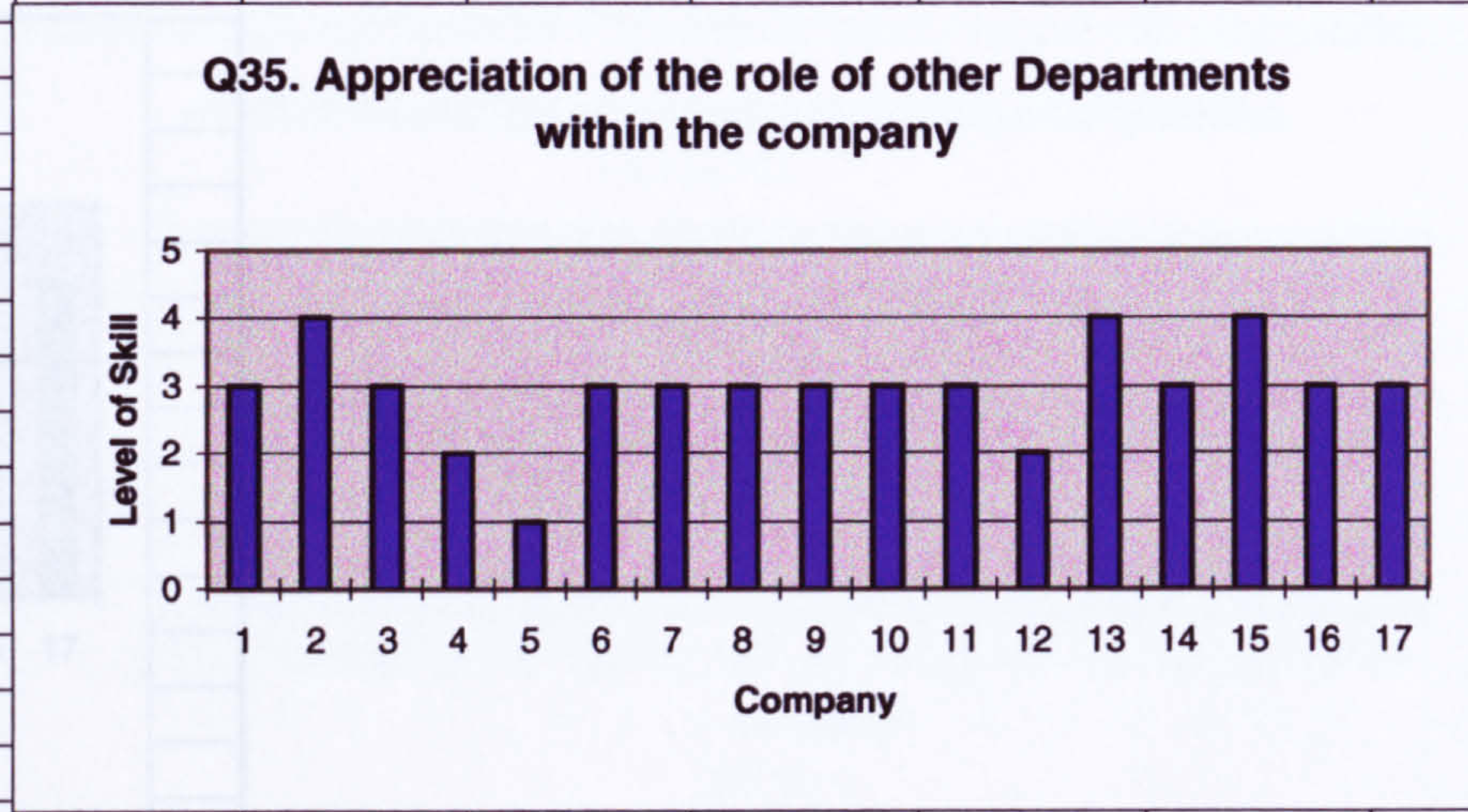


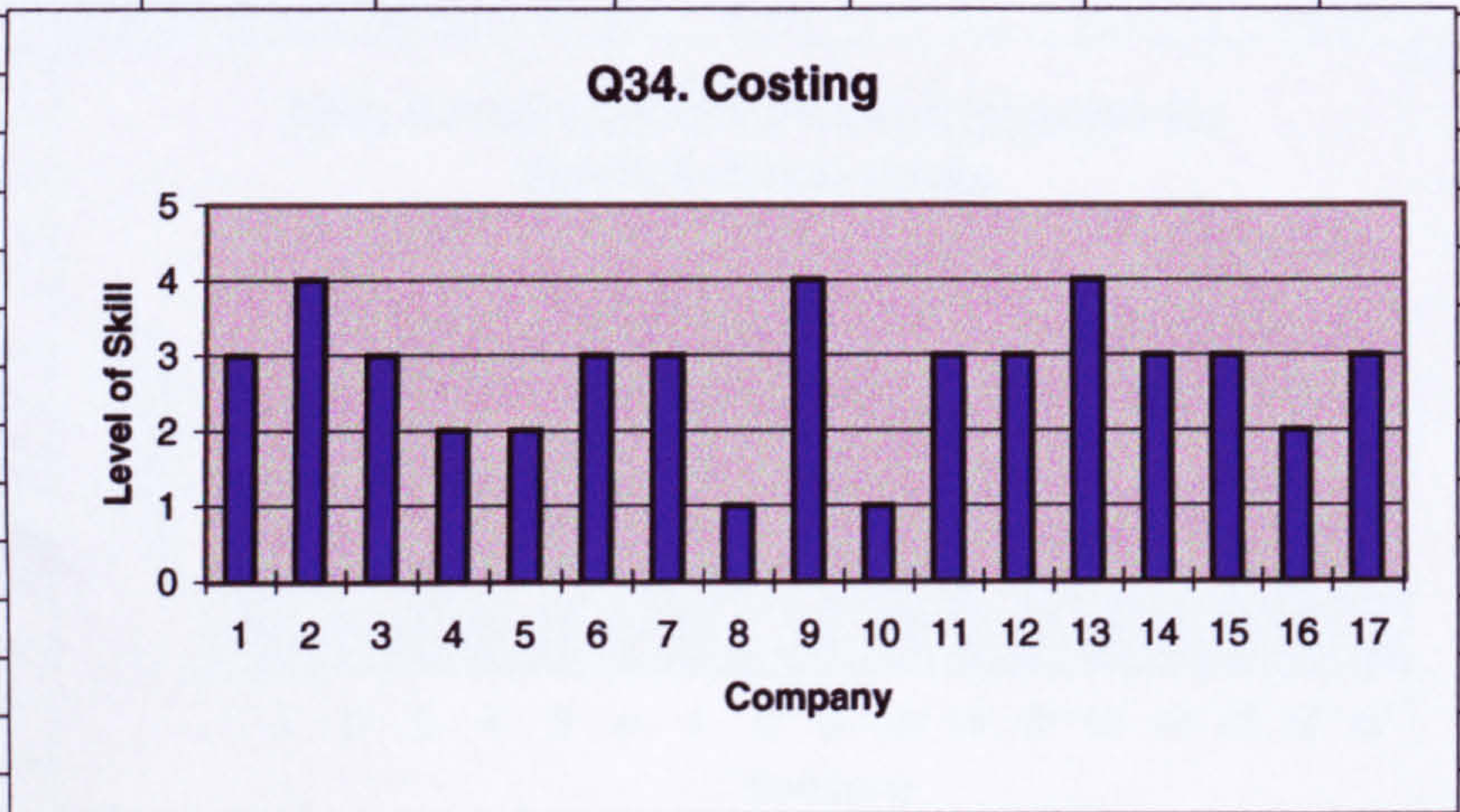


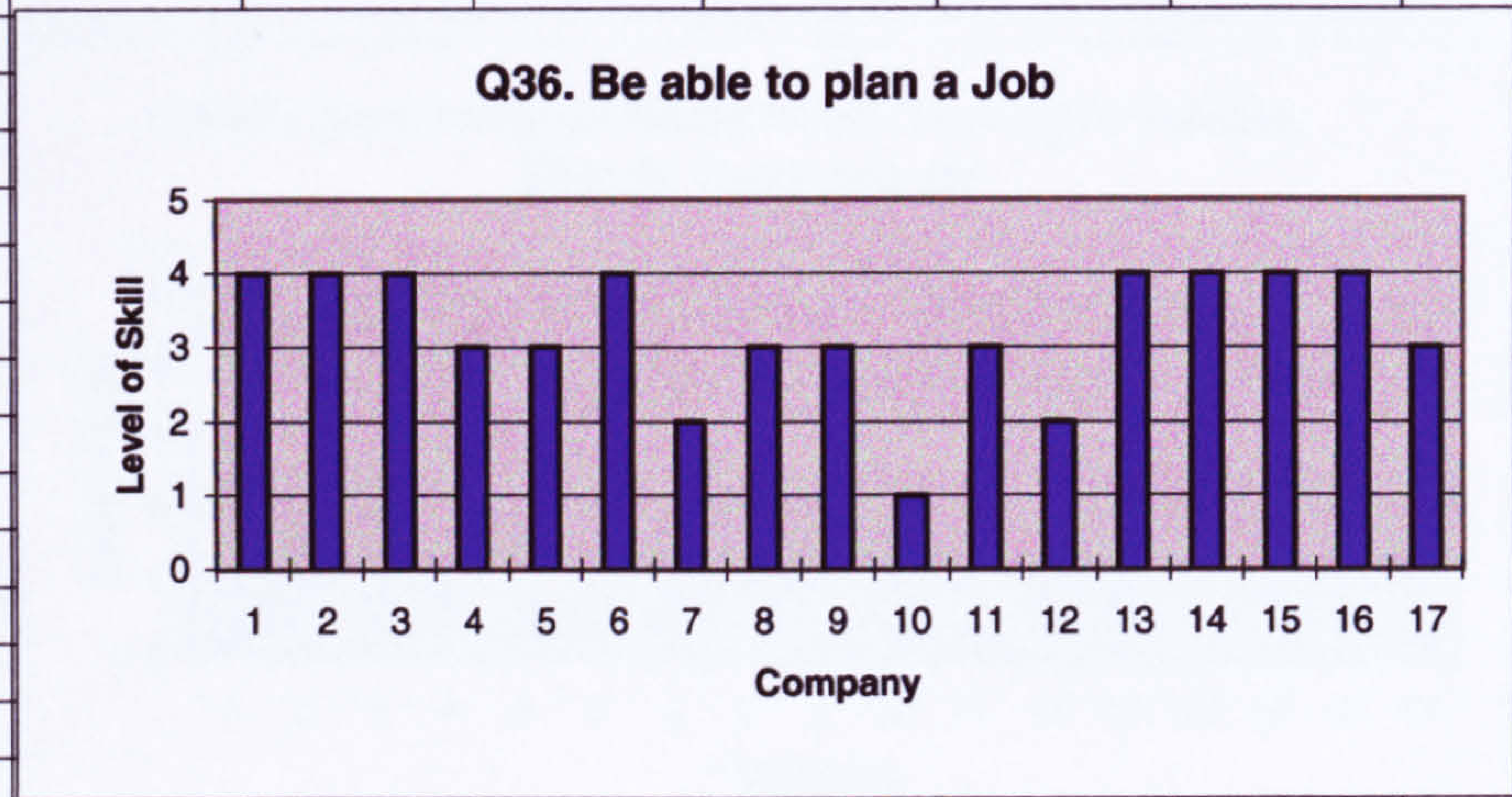
Company Responses Charts 4.9

6. Business cont'd



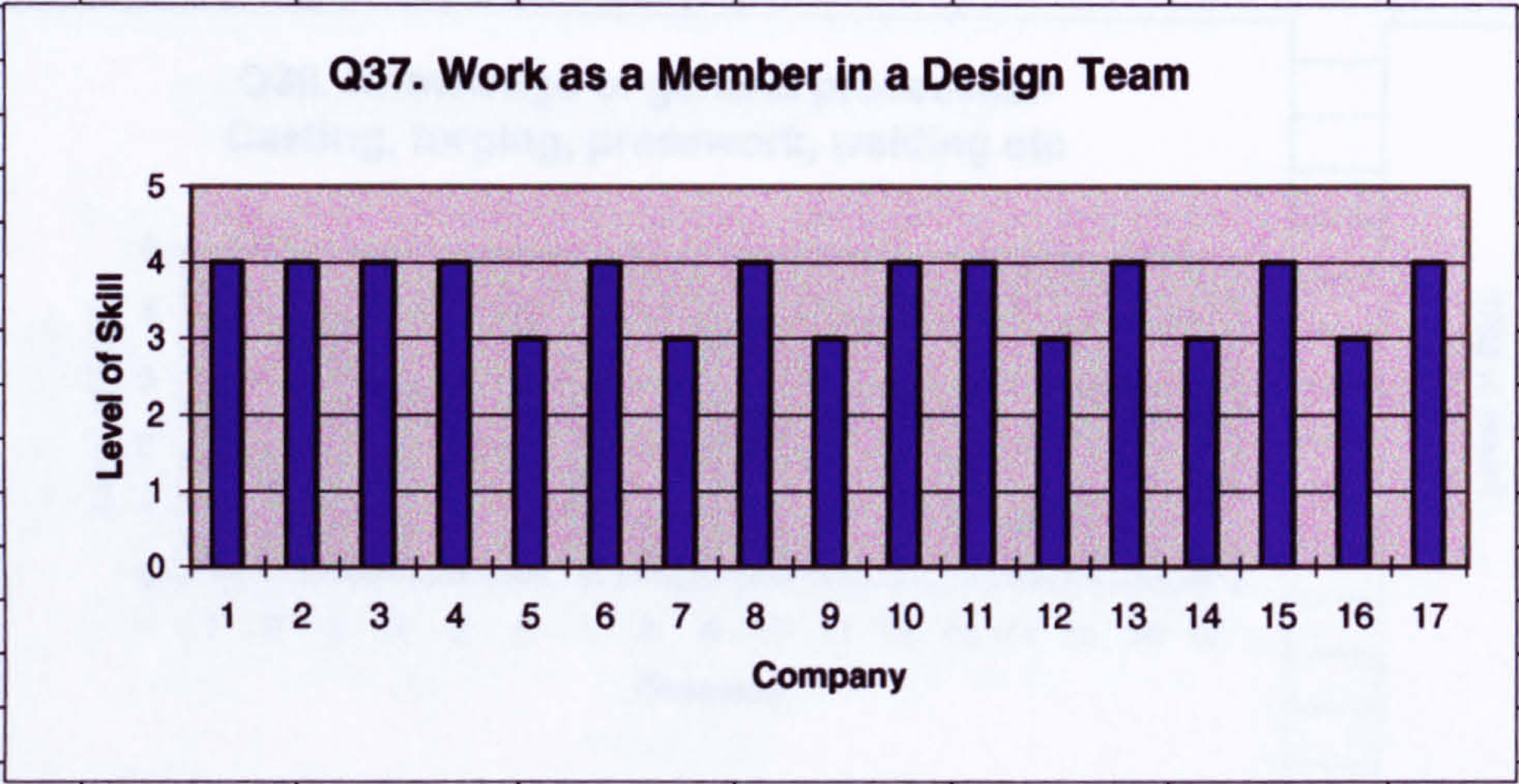






Company Responses Charts 4.10

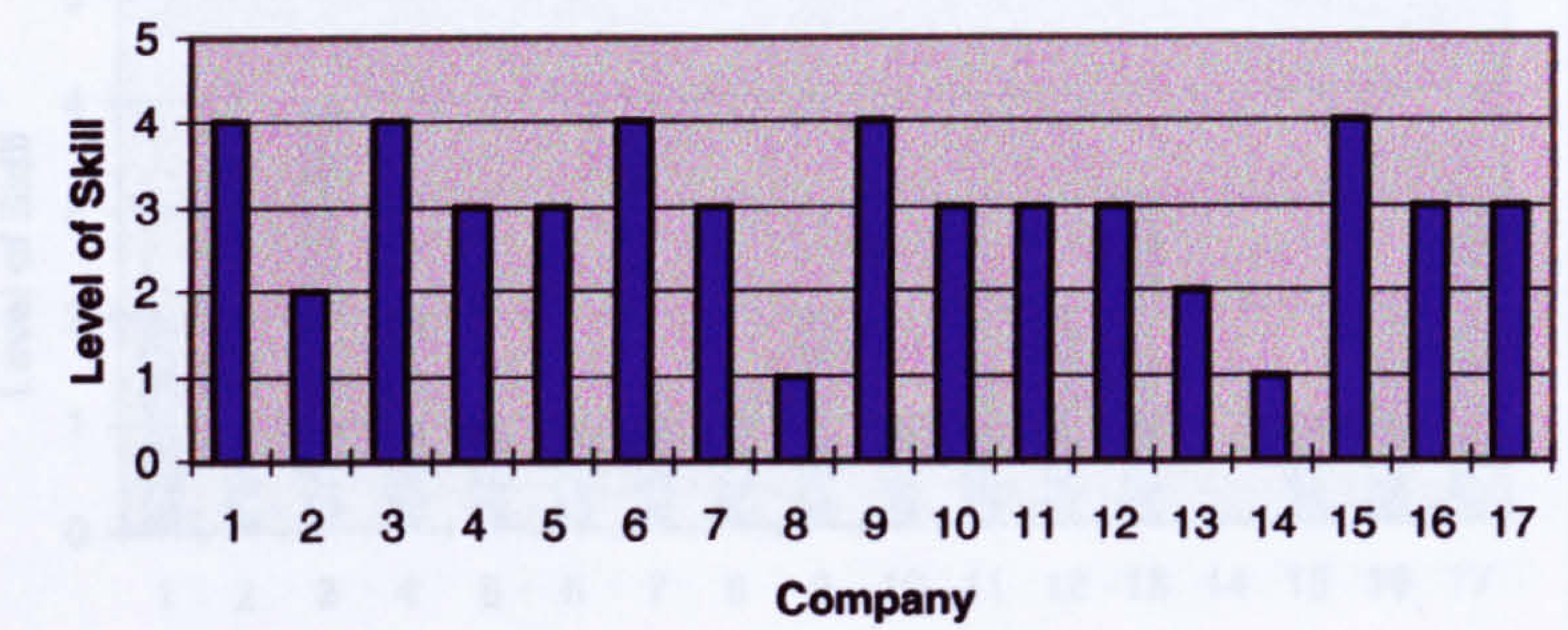
6.Business cont'd



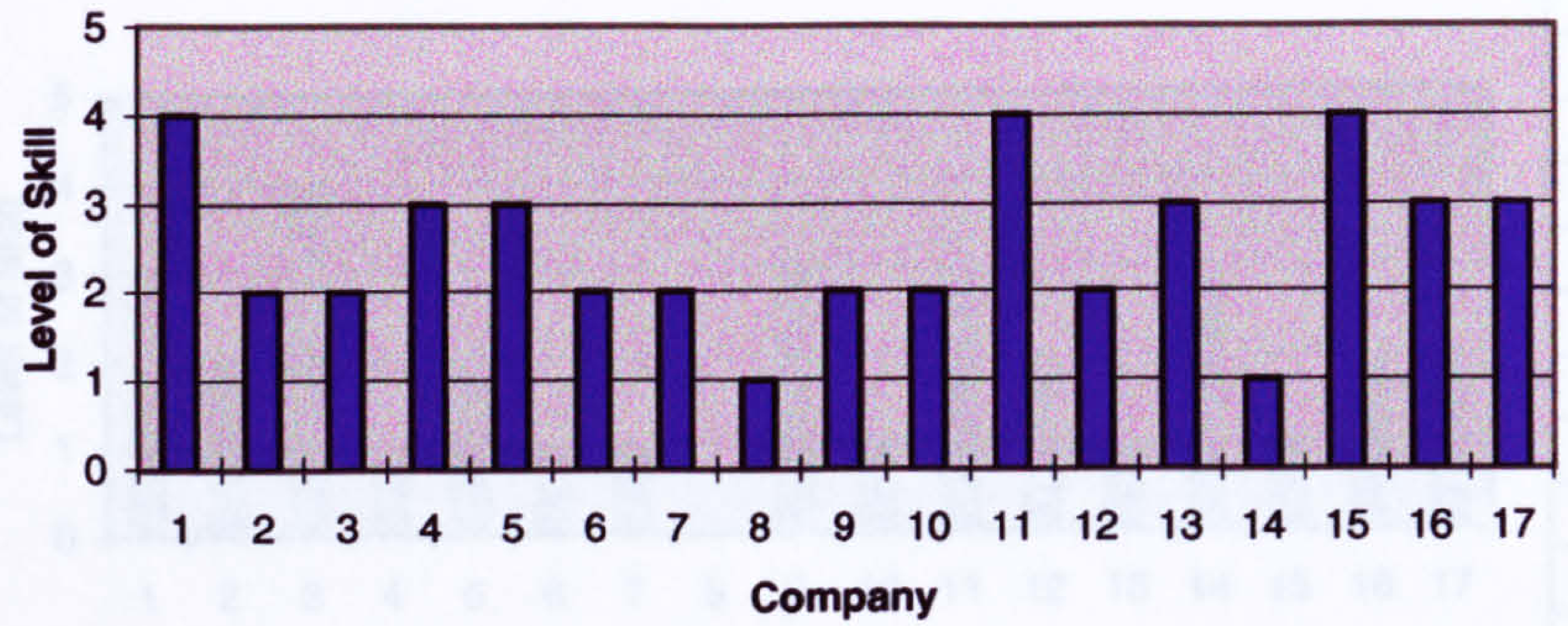
Company Responses Charts 4.11

7. Manufacturing Methods

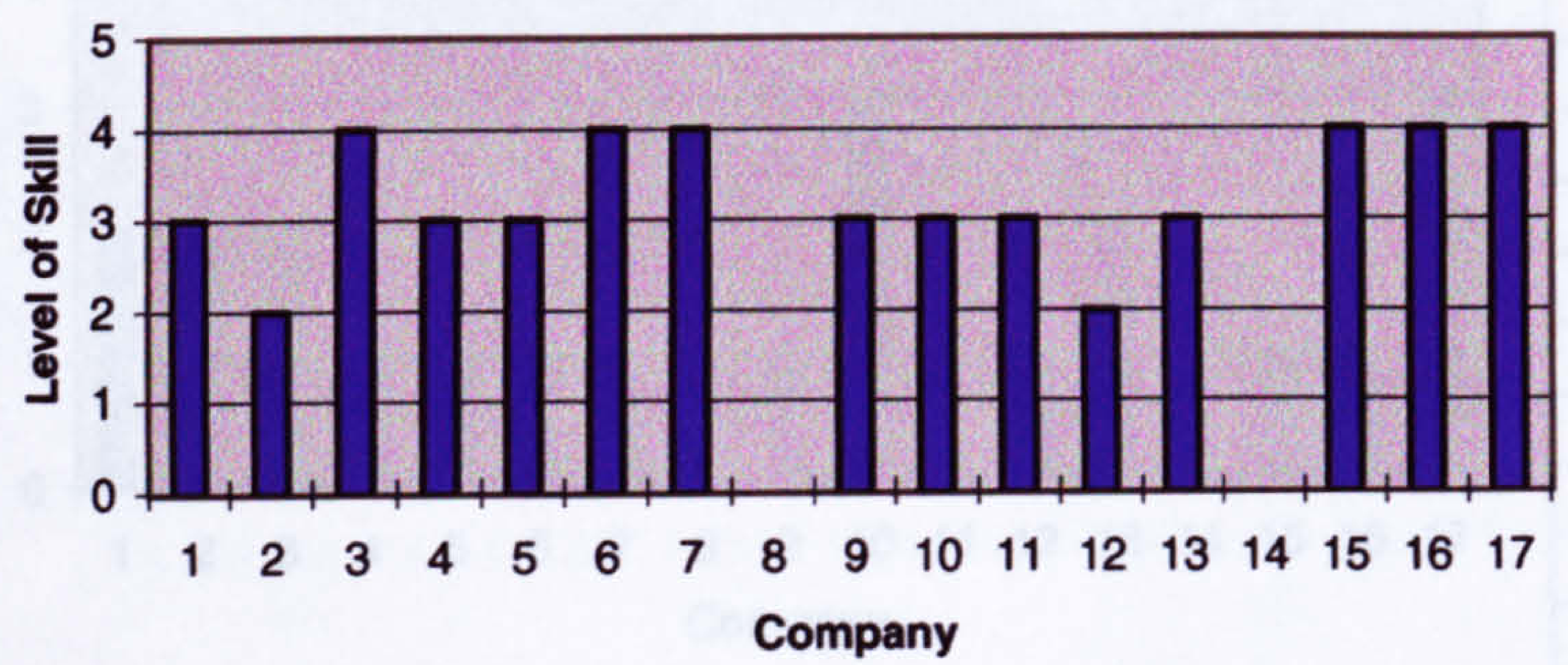
Q38. Knowledge of general processes:- Casting, forging, presswork, welding etc



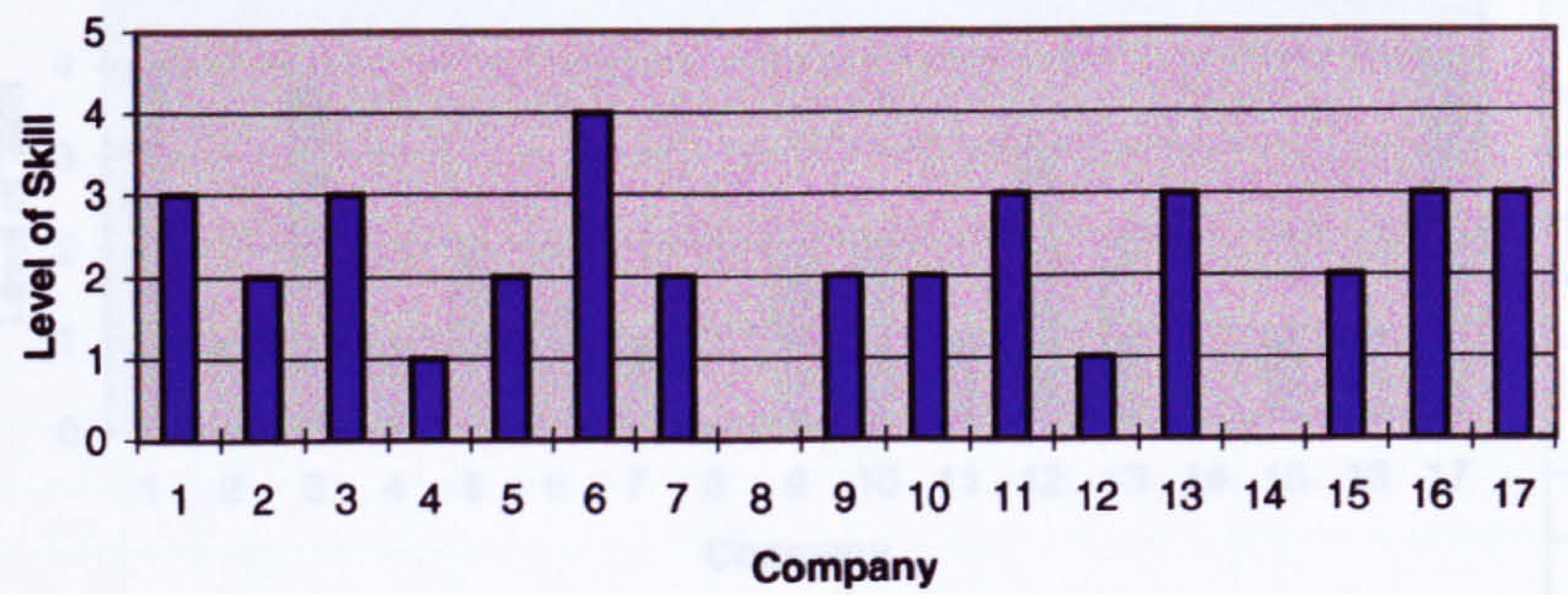
Q40. Knowledge of material properties for plastics



Q39. Knowledge of material properties for steels & other metals

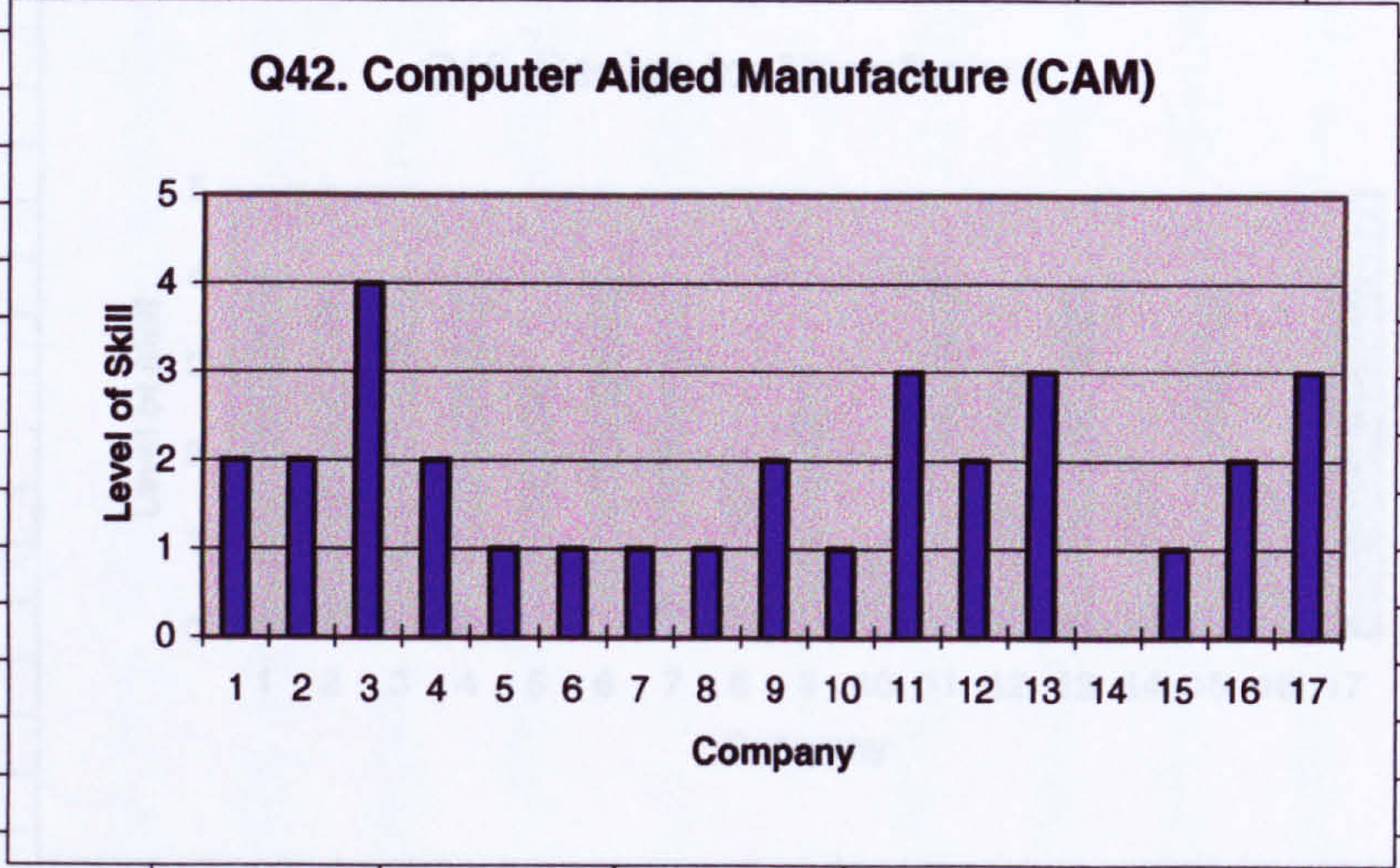


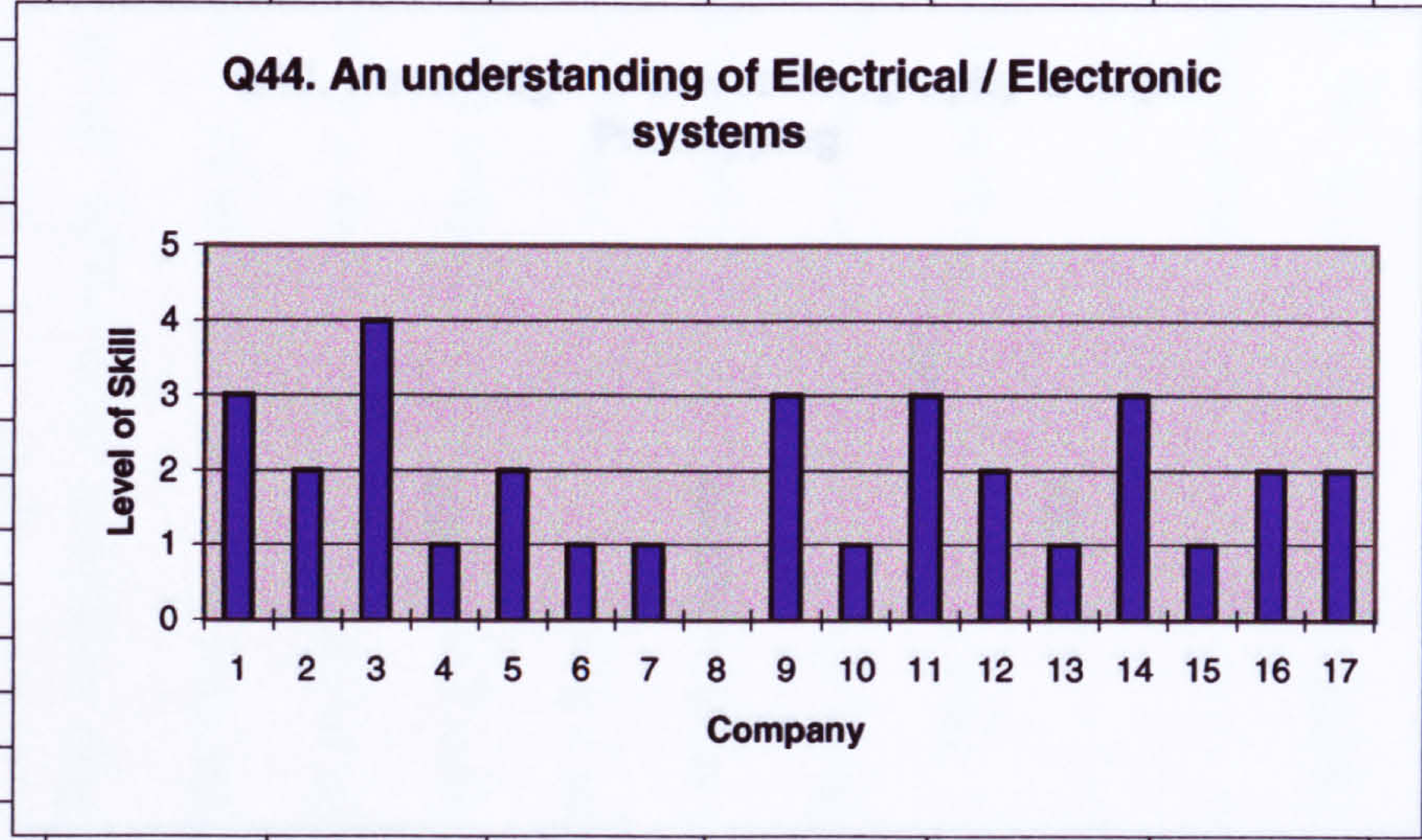
Q41. Knowledge of Component Testing ie Tensile, Impact, Hardness etc

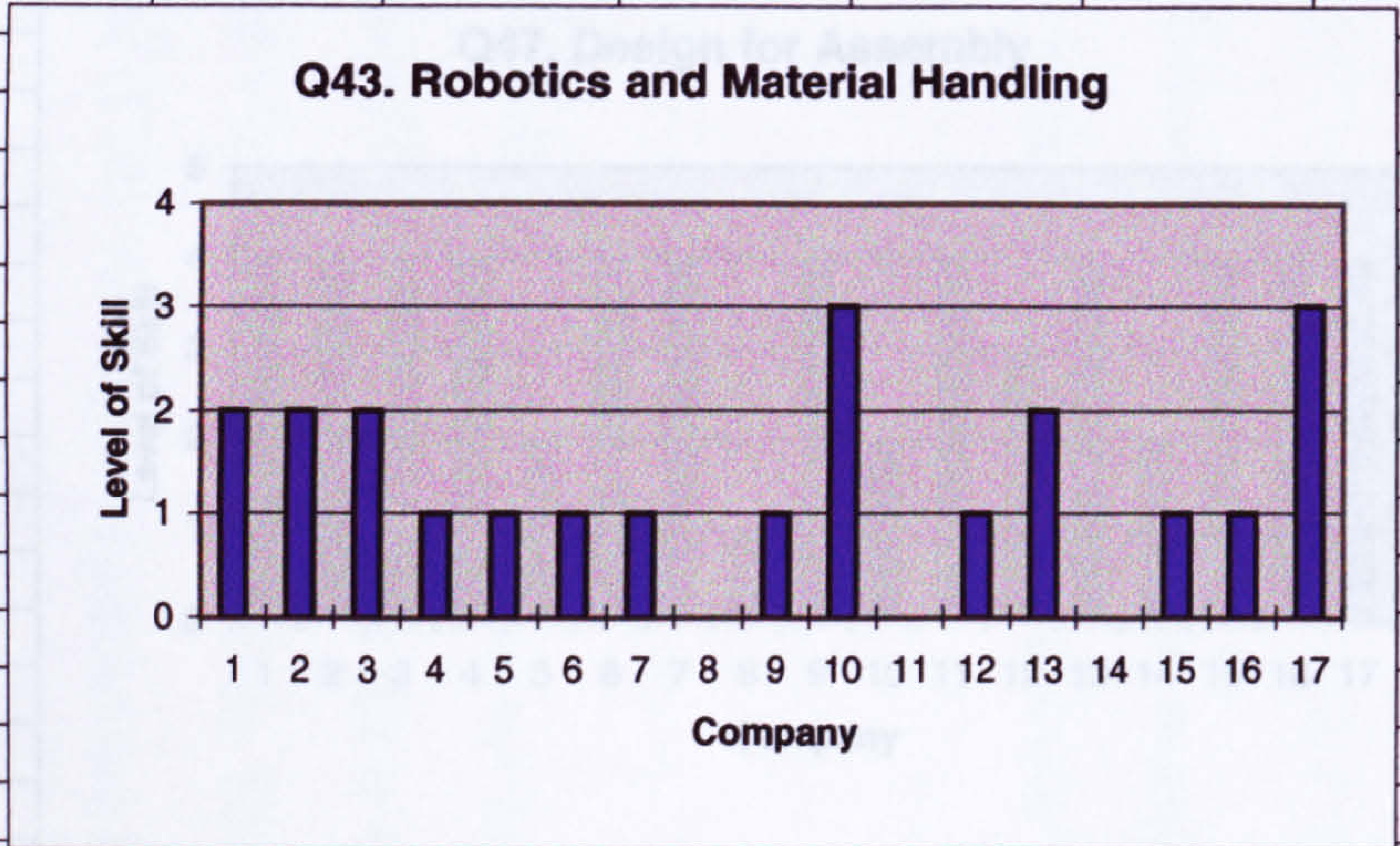


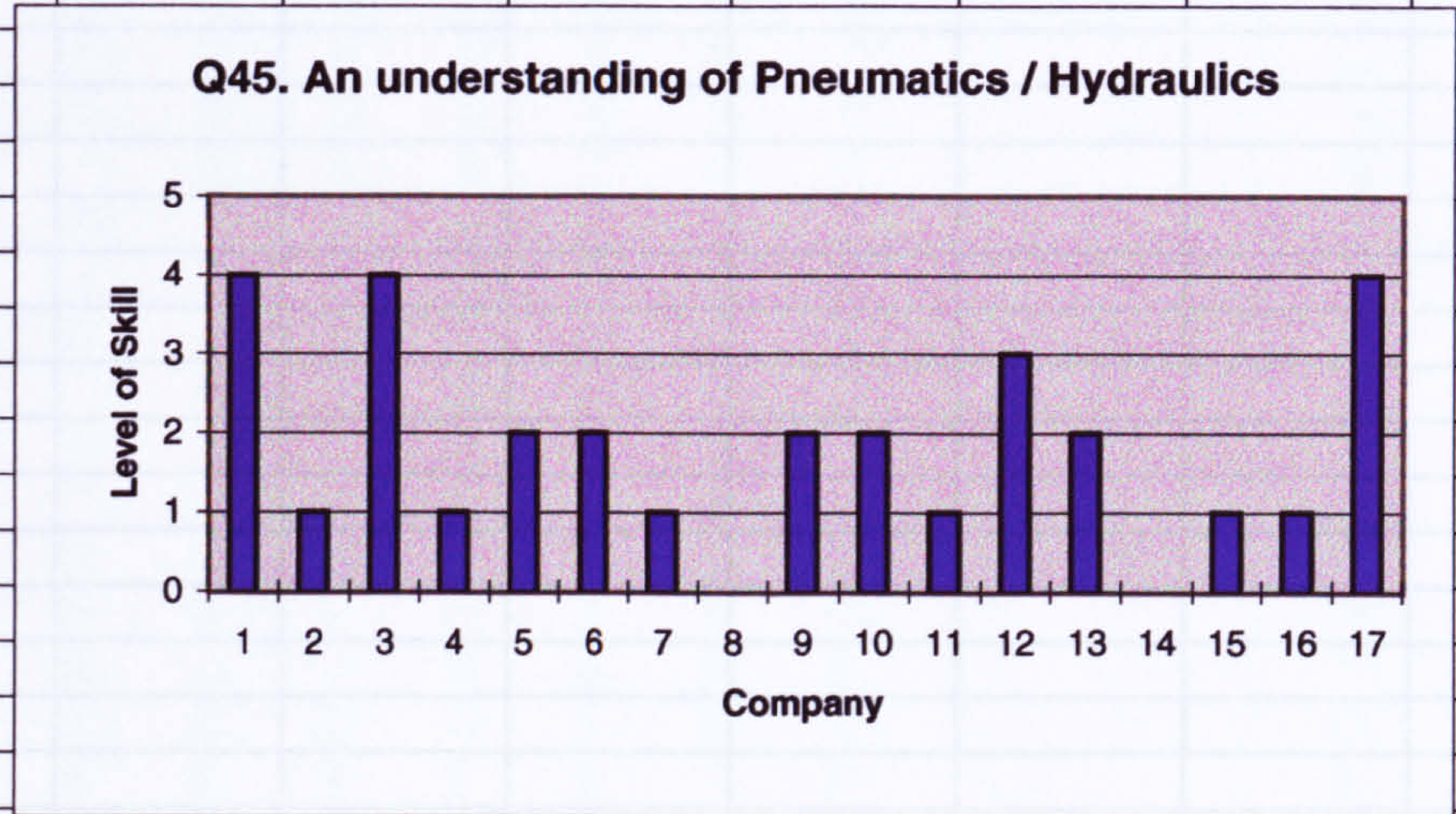
Company Responses Charts 4.12

7. Manufacturing Methods cont'd



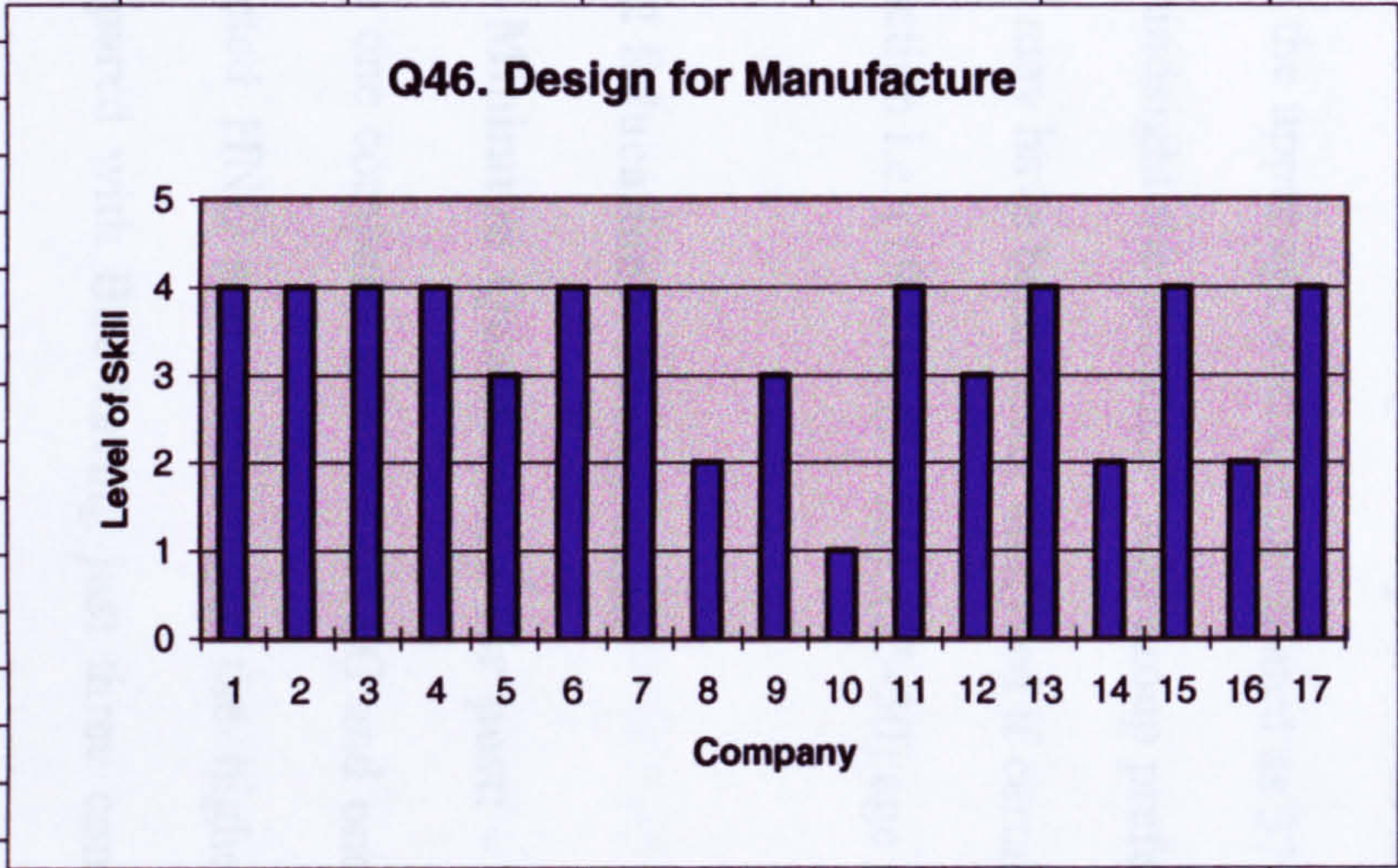


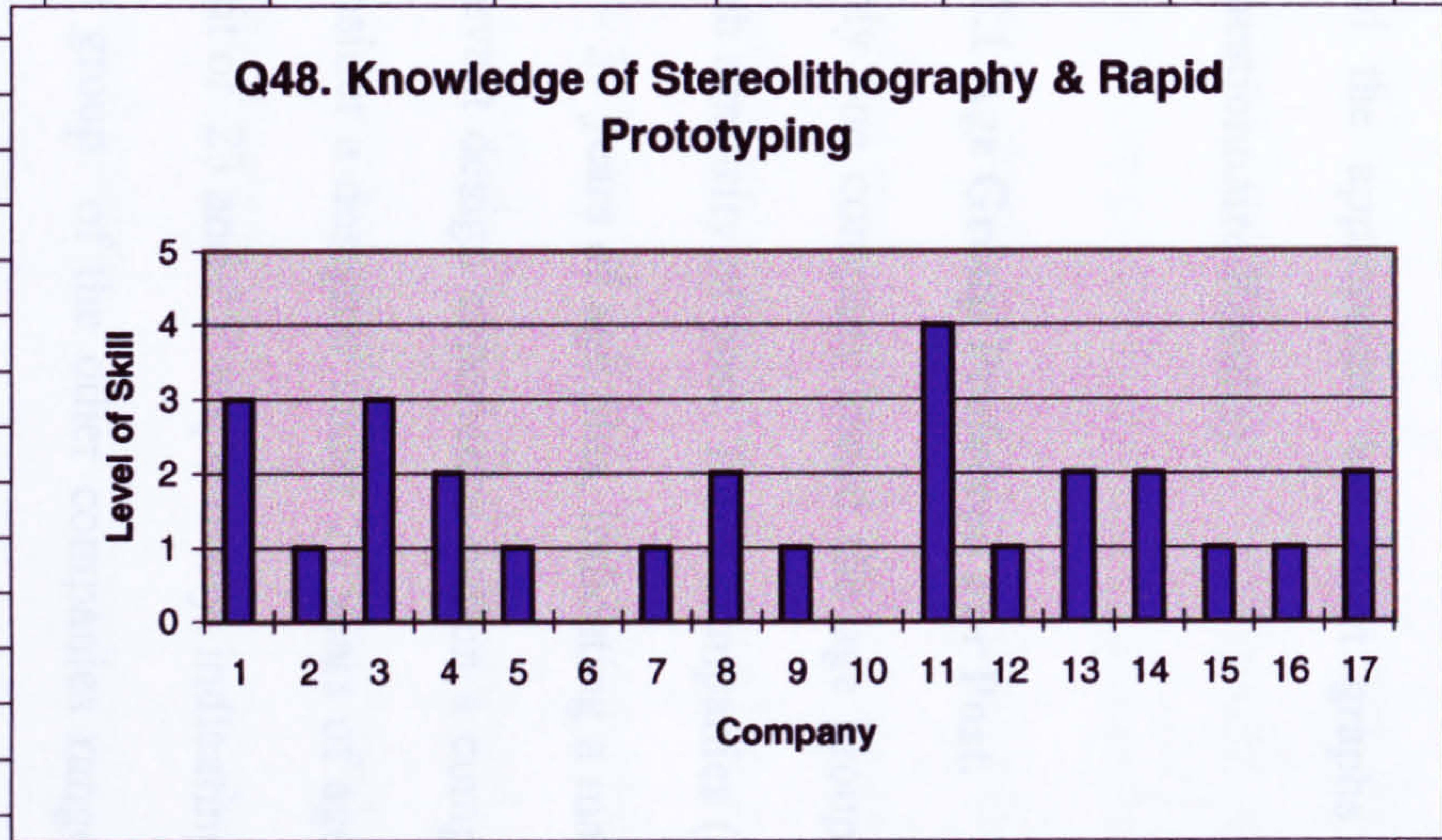


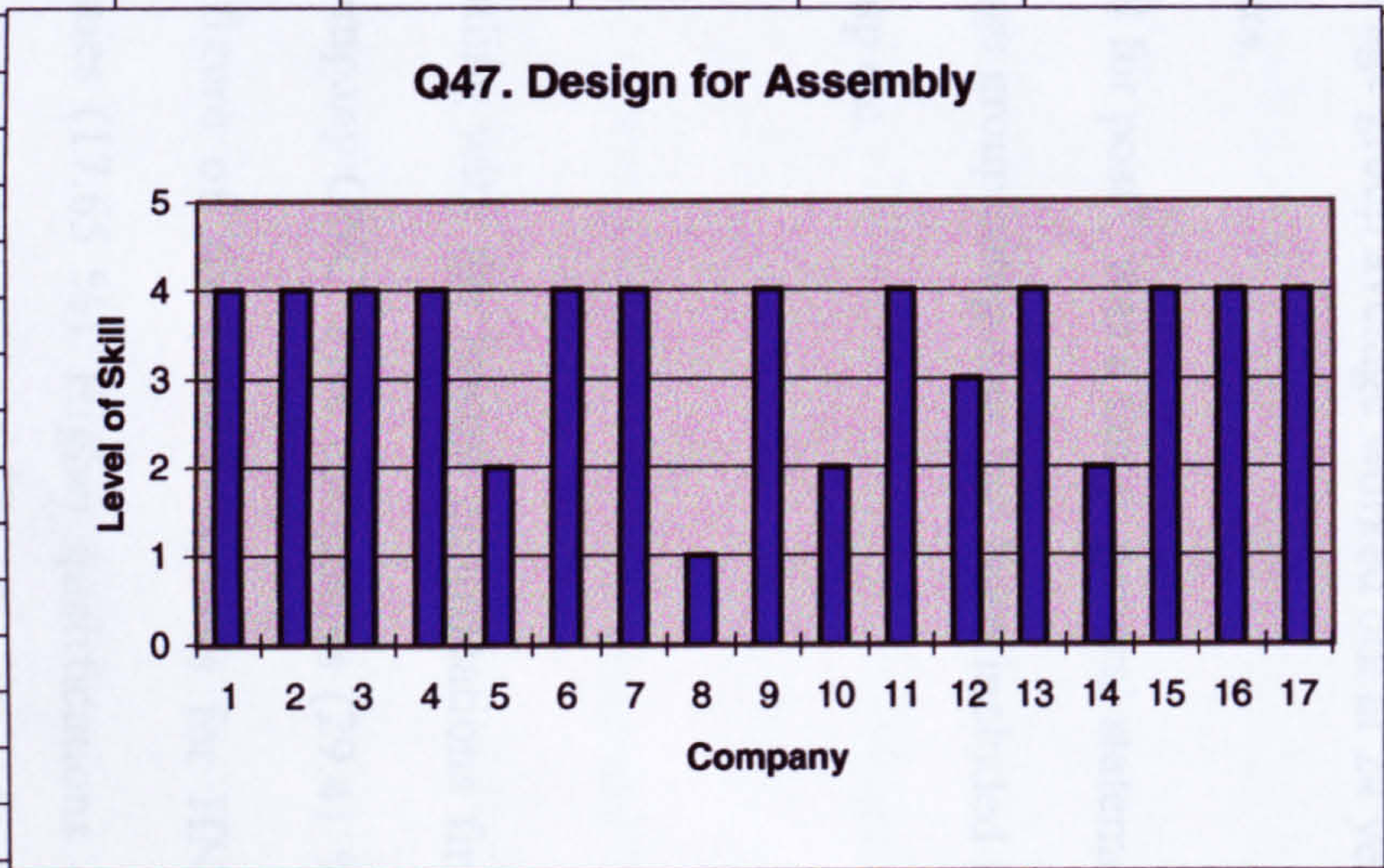


Company Responses Charts 4.13

7. Manufacturing Methods cont'd







Company Responses Charts 4.14

4.7 Company Questionnaire Analysis Of Results

The following analysis of results is based upon the findings from **Tables 4.1, Table 4.2** and the appropriate bar chart graphs under the previous heading (4.6 Company Questionnaire Results).

4.7.1 Age Group Preferred For Post.

Only one company stated the age group would be job dependant, presumably linked with seniority of post. Three companies (approximately 18%) preferred a designer aged 28 - 30 years of age plus, indicating a mature designer possibly with at least five years' relevant design experience within a company. Thirteen of the companies (76%) would consider a designer under 25 years of age, two of these companies with an upper age limit of 23 and 25 respectively, indicating a younger newly qualified person. The upper age group of the other companies ranged from 35 - 40 years with three companies having a maximum age of 50 years. The lower age group average worked out at 24 years and the upper age average calculated as 37 years.

In hindsight the question "Age group preferred for post" was a fairly general statement and may have been better analysed if certain age group categories had been included for selection i.e. (19-21), (21-25), (25-30) age group etc.

4.7.2 Educational Background

***Q1.* Minimum Qualification for post:** - Dealing with the lowest qualifications first, only one company selected BTEC and one company ONC. Five companies (29.41 %) selected HNC and surprisingly the highest figure of six (35.29 %) was for HND compared with BSc having just three companies (17.65 %). Higher qualifications of

MSc and PhD were not selected at all. One company stated the qualification would be job dependant.

Q2. **What study area is preferred by the company? : -** Five companies (29.41 %) selected Product Design. Surprisingly, none specifically wanted Electrical or Electronic, which design staff members had considered a growth area. These findings for Electrical and Electronic would correspond at a later stage with the very low number of students, ones and twos, wishing to study Consumer Electronics which was introduced in October 1996 as an option route within the BSc CAPD course.

Six companies (35.29 %) chose Mechanical, none Manufacture, two (11.76 %) Automotive and four (23.53 %) opted for All areas.

Q3. **If an applicant has higher Qualifications i.e. PhD would this put the company off ?** Five companies (29.41 %) said that it would, Eleven of the companies (64.71 %) said it would not, with one company stating it would be dependant upon the individual.

Q4. **Is graduate member of a professional body important?** 14 of the companies (82.35 %) stated graduate membership of a professional wasn't important, only three companies (17.65 %) stated this was advantageous.

Q5. **If YES to *Q4* which professional body is preferred?** Four companies responded to this, one stated any professional body the other three opted for Mechanical Engineering.

Q6. **Is Chartered Engineer Status important once working for the company ?** A surprising number (70.59 %) representing 12 of the companies said this was Not important, there was no response from one company with the other four companies (17.65 %) stating "Chartered Engineer Status was important once working for the company".

Q7. **If YES to *Q6* which professional body is preferred?** From the four companies who responded with YES, one selected any professional body with the other three companies preferring Mechanical Engineering.

4.7.3 Work Experience

Q8. **Is previous work experience essential** ? Six companies (35.29 %) stated that previous work experience was not essential. However, a large percentage (64.71 %) representing eleven companies stated it was essential. This appears to confirm the fact that students who have studied on a sandwich degree programme with one year's industrial experience tend to be in a better position than their full time counterparts when seeking employment once graduated. In fact, there has been a significant number of BSc CAPD students who have been offered positions within the company where they carried out their work experience.

The four year sandwich degree programme with the work experience year may be in jeopardy in the future with the advent of student fees, introduced for the first time in 1998, in that the student or company will have to pay a proportion of fees to the University whilst on placement. This may be seen as yet another financial burden from the student's point of view, who may opt for the three year full time programme. One may find that the placement year becomes a thing of the past if support is not forthcoming from industry or other sources.

Q9. **If YES from *Q8* minimal number of years**. The replies ranged from 1 year up to a maximum of 10 years. The average worked out at (44/10*100%) = 4.4 years.

Q10. **Is the area of work experience important?** Thirteen companies (76.47 %) stated that it was an important factor with just two companies (11.76 %) stating it wasn't. Two of the companies made no response.

Q11. **If YES from Q10 what area of work experience is most appropriate for the company?** Three companies (17.65 %) did not respond. Five companies (29.41 %) preferred the work experience to be appropriate to the position and five companies (29.41 %) selected Product Design. Mechanical engineering was selected by three companies (17.65 %) and one company (5.88 %) opting for Automotive.

Q12 **Is it important to have continuing professional development for staff once in the company to update their skills?** Sixteen (94 %) out of the seventeen companies stated it was important to have CPD which was encouraging when one is promoting life long learning.

4.7.4 Manual Drawing Board Ability and Communication Skills

Q13. **Produce Design Sketches / Diagrams.** The majority of companies (58.82 %) and (23.53 %) required a level of skill of Good or Very Good respectively.

Q14. **Read and Interpret Engineering Drawings.** Virtually all the companies perceived this as a very important skill for new designers, nine companies (52.94 %) selecting Very Good and another (41.18 %) seven of the companies selecting skill levels of Good.

Q15. **Produce Part Drawings.** A mixed response from this question, clearly some companies see this as very important with a similar number of companies, five (29.41 %) in each case opting for Very Good or Good skill levels respectively. Six (35.29 %) chose a skill level of Competent with only one company selecting a skill level of Basic.

Q16. **Produce Detail Drawings.** Similar findings to *Q15* with five companies (29.41 %) selecting Very Good, seven companies (41.18 %) opting for Good, three (17.65 %) chose Competent and the other two companies (11.76 %) requiring their designers with just a Basic aptitude.

Q17. **Think in 3D.** This was seen as a very important skill, with only one company selecting Competent, the other sixteen companies chose either Good (41.18 %) or Very Good (52.94 %).

Q18. **Rendering Skills Using Marker Pens.** No companies selected Very Good, five companies (29.41 %) chose Good as a skill level, four companies (23.53 %) chose Competent, four companies a Basic skill level with four of the companies requiring no skill at all in this particular area.

[1]Kemnitzer (1983, p10) stated "The overwhelming reason for the frequent use of markers in professional studios is that they facilitate quick sketching and rendering. Because sketches and renderings can be executed in marker faster than in other media and because the results are at least as good and often better, marker renderings are economical and help to keep the design process moving at an efficient pace. A greater number of design concepts can be communicated to the design team and client and presumably more informed, thoughtful and exciting design decisions result ".

This may have been the case in the past, the question to be asked, "Is this a Dying Art for the majority of Designers in the future"? [2]Powell et al (1987, p42) commented "commitment to a product depends entirely on results, as soon as a better medium appears markers will be abandoned. So far, to great relief of the manufacturers, nothing better has come to the fore although computer-aided design may supersede them one day" With the advent and development of 3D computer-generated renderings producing increasingly sophisticated shaded images, and the added advantage of speed to modify

[1] KEMNITZER, Ronald B. (1983) *Rendering With Markers.* Watson-Guptill Publications, p.10.
[2] POWELL, Dick. and MONAHAN, Patricia. (1987) *Advanced Marker Techniques.* London: Macdonald, p.42.

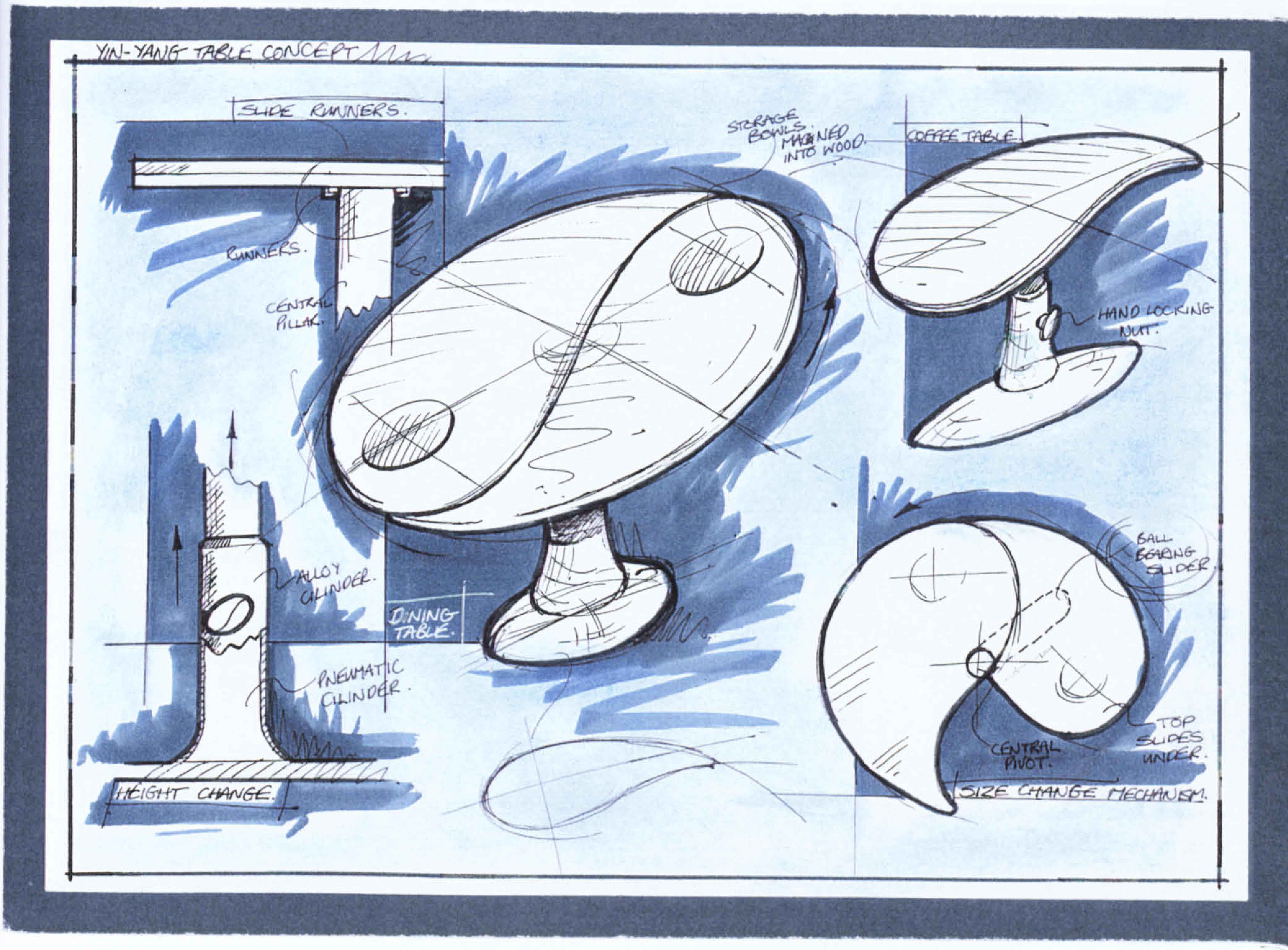
and update the design, this would appear to be the case. In the future hand renderings may only be sought after by a limited number of companies at the concept stage.

The following two pages show the effective use of hand sketches and renderings, produced by a Level 2 student with an art background for the Design Practice module. The renderings are very descriptive showing a large amount of detail, communicating both aesthetic and technical information.

Q19. **Produce a Physical Model of a Product in Foam, Wood etc.** The responses would indicate that only a few companies require a high degree of skill in this area. One company (Bathroom Products) opting for Very Good and another company (New Product Development and Product Design) selecting Good, as one may expect from these type of companies at the cutting edge of concept design. A skill level rated as Competent was chosen by six companies (35.29 %) and four companies (23.53 %) only required a Basic knowledge. Five companies (29.41 %) chose None, requiring no skill level at all in this particular field.

The findings would indicate, and it is the Author's opinion, that the skill of producing these types of models will be less sought after in the future with the fast growing use and development of modern Rapid Prototyping techniques, such as sterolithography, made readily available.

Q20. **Produce hand written reports**. All companies indicated a skill requirement in this area ranging from Very Good for four companies (23.53 %), a Good skill level selected by eight companies (47.06 %), four companies selected a Competent skill level and one company (5.88 %) just a Basic skill level.



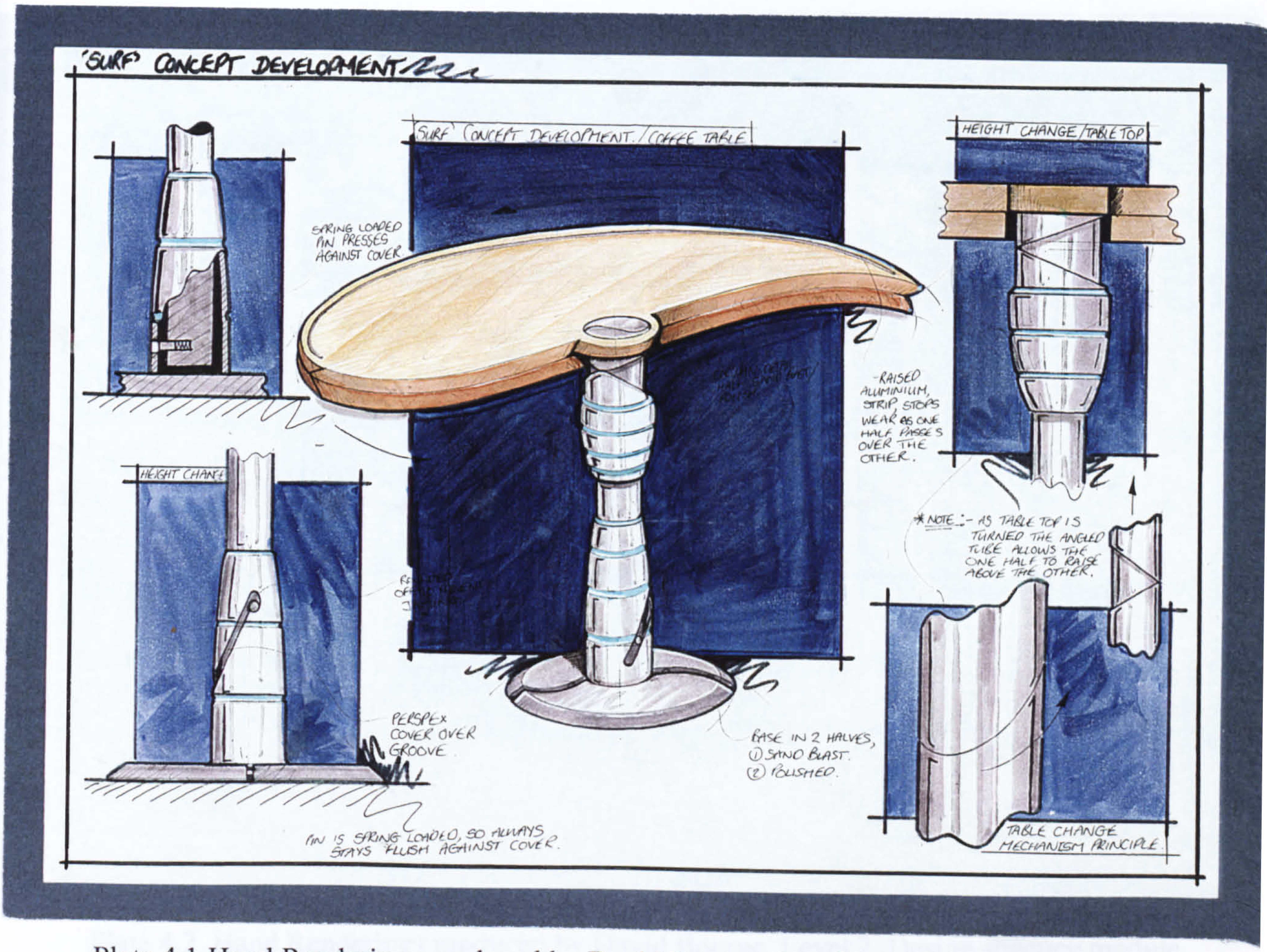
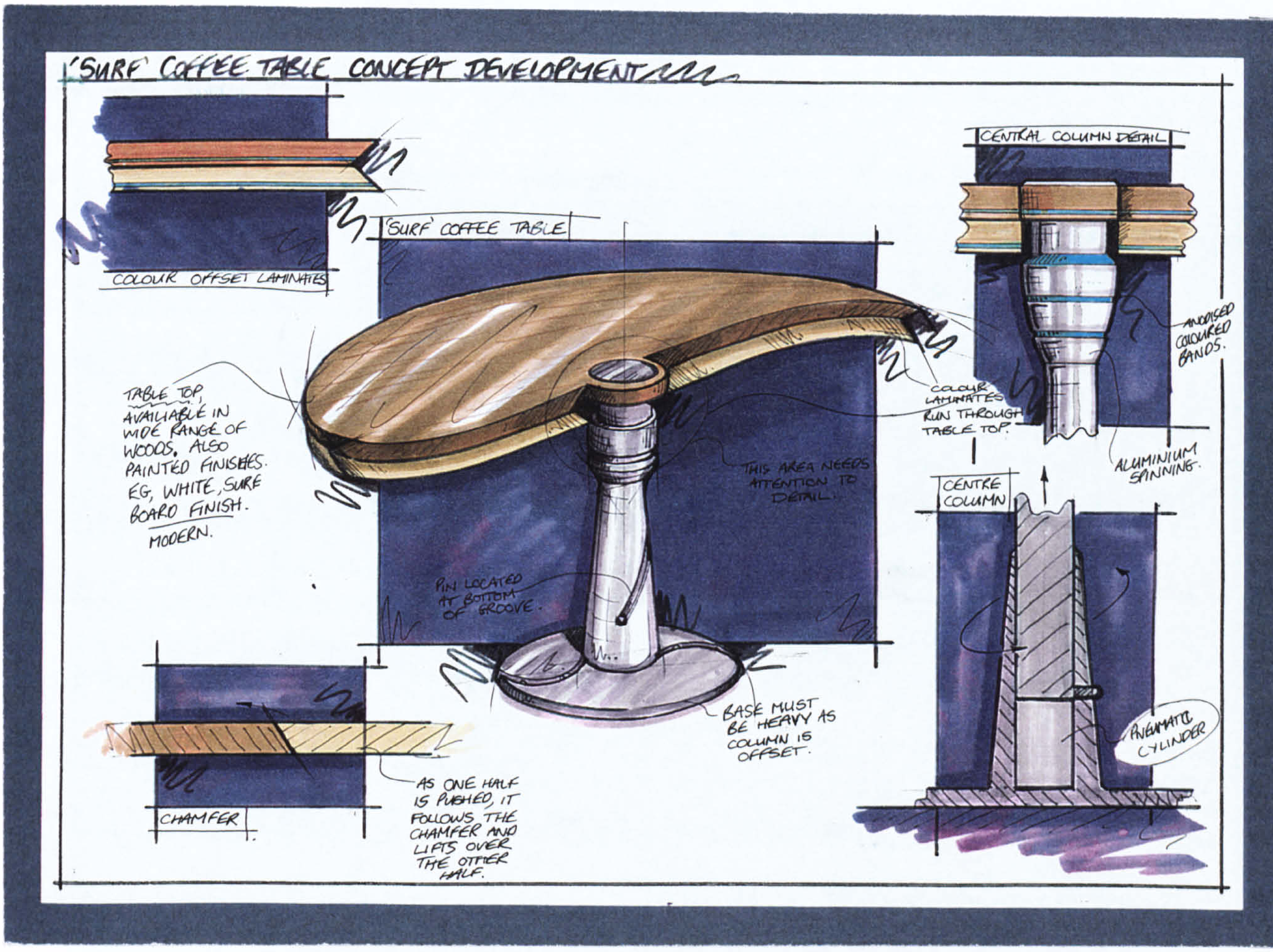


Plate 4.1 Hand Renderings produced by David Bourne. Level 2, Design Practice module. The design of a coffee table that transforms into a dining table for a Luxury Yacht.



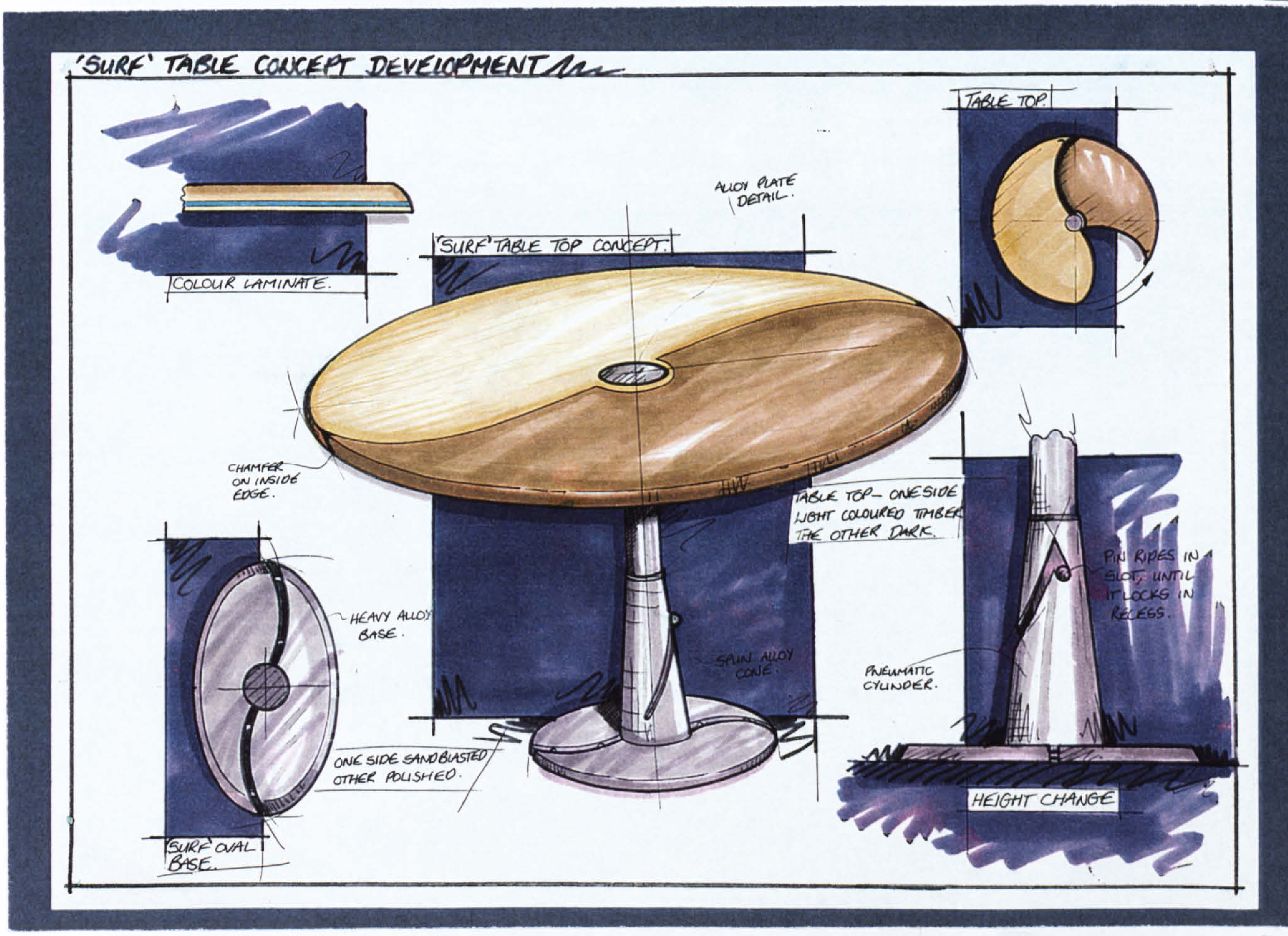


Plate 4.2 Hand Renderings produced by David Bourne. Level 2, Design Practice module. The design of a coffee table that transforms into a dining table for a Luxury Yacht.

4.7.5 Use of Computers in Design.

***Q21.* Operate a CAD system for 2D drawing.** The findings show virtually all the companies require Designers with a high level of skill in this particular area, ten companies (58.82 %) selecting a skill level of Very Good, and six companies (35.29 %) selecting Good with only one company selecting Basic.

Operating a CAD system for 2D drafting and 3D modelling has always formed a significant part of the learning experience in many of the modules for students studying BSc CAPD. Often termed the "Bread and Butter" of this industry by the Author because design students have consistently obtained jobs and earned good financial rewards in this area.

***Q22.* Operate a CAD system for 3D Modelling.** Most companies required a certain amount of skill in this area but surprisingly not as significant as Q21. Four companies (23.53 %) opted for Very Good, two companies (11.76 %) Good, eight companies (47.06 %) Competent, two companies (11.76 %) Basic and one company (5.88 %) None. As 3D computer modellers become more widely used by companies it is most likely the skill levels required will rise accordingly. More and more companies are seeing the benefits and making use of these techniques due to reduced hardware and software costs. Increased power of PC's, 3D modellers which are Feature based and Parametric Design, i.e. dimension driven, allow the 3D model to be modified quickly on screen with Orthographic views in 1st or 3rd angle projection, sectioned or other projection views produced in a fraction of the time. The added bonus of the CAD data being produced in various formats and transferred across networks and downloaded to CNC or other prototyping modelling facilities make it a very desirable acquisition.

The following two pages show the effective use of 3D Parametric design software (BSc CAPD final year student project).

Plate 4.3 BSc CAPD Final Year Project. Cable Tension Gauge Assembly designed and produced by Chris Melia. Modelled in ProEngineer

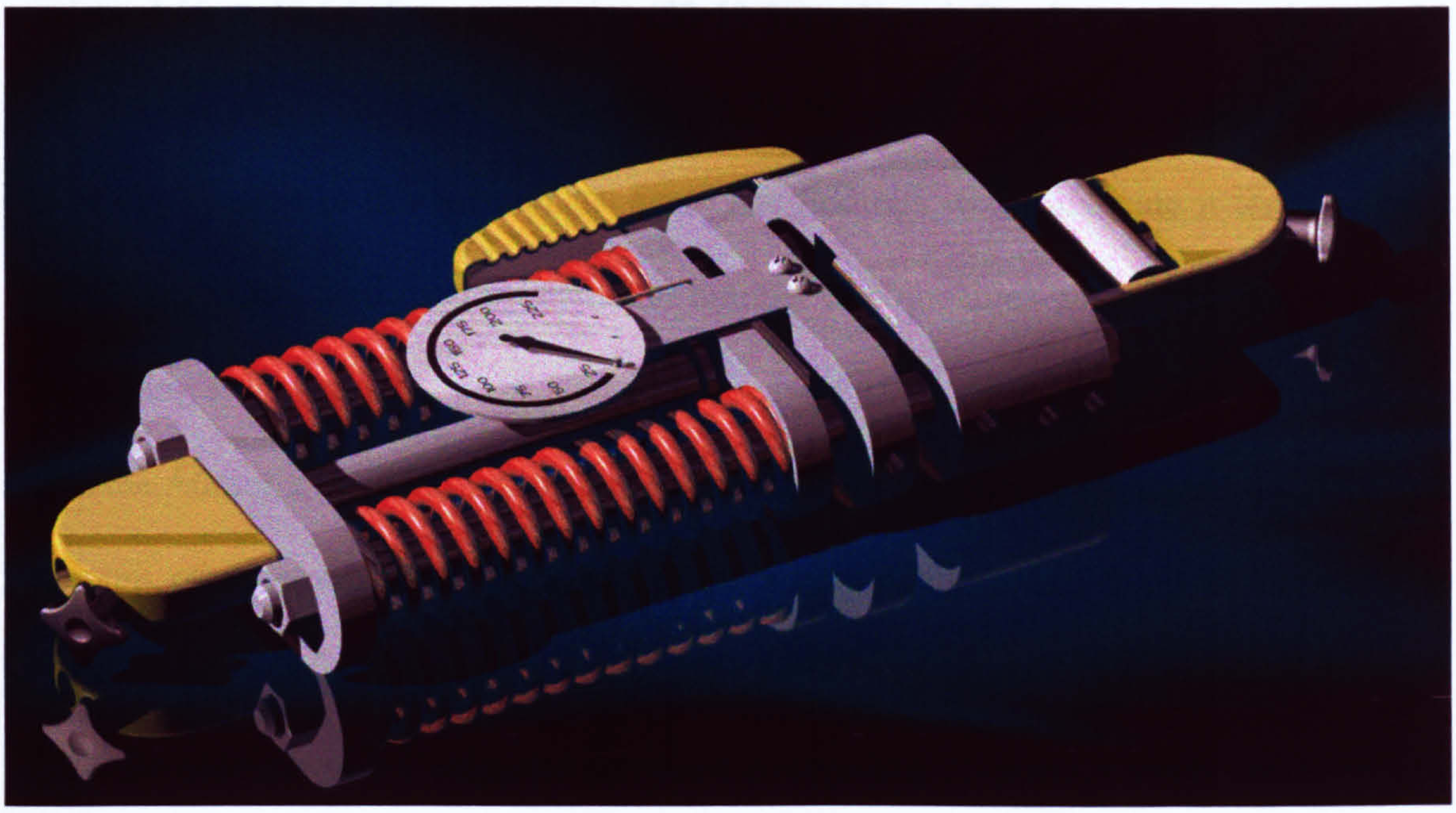
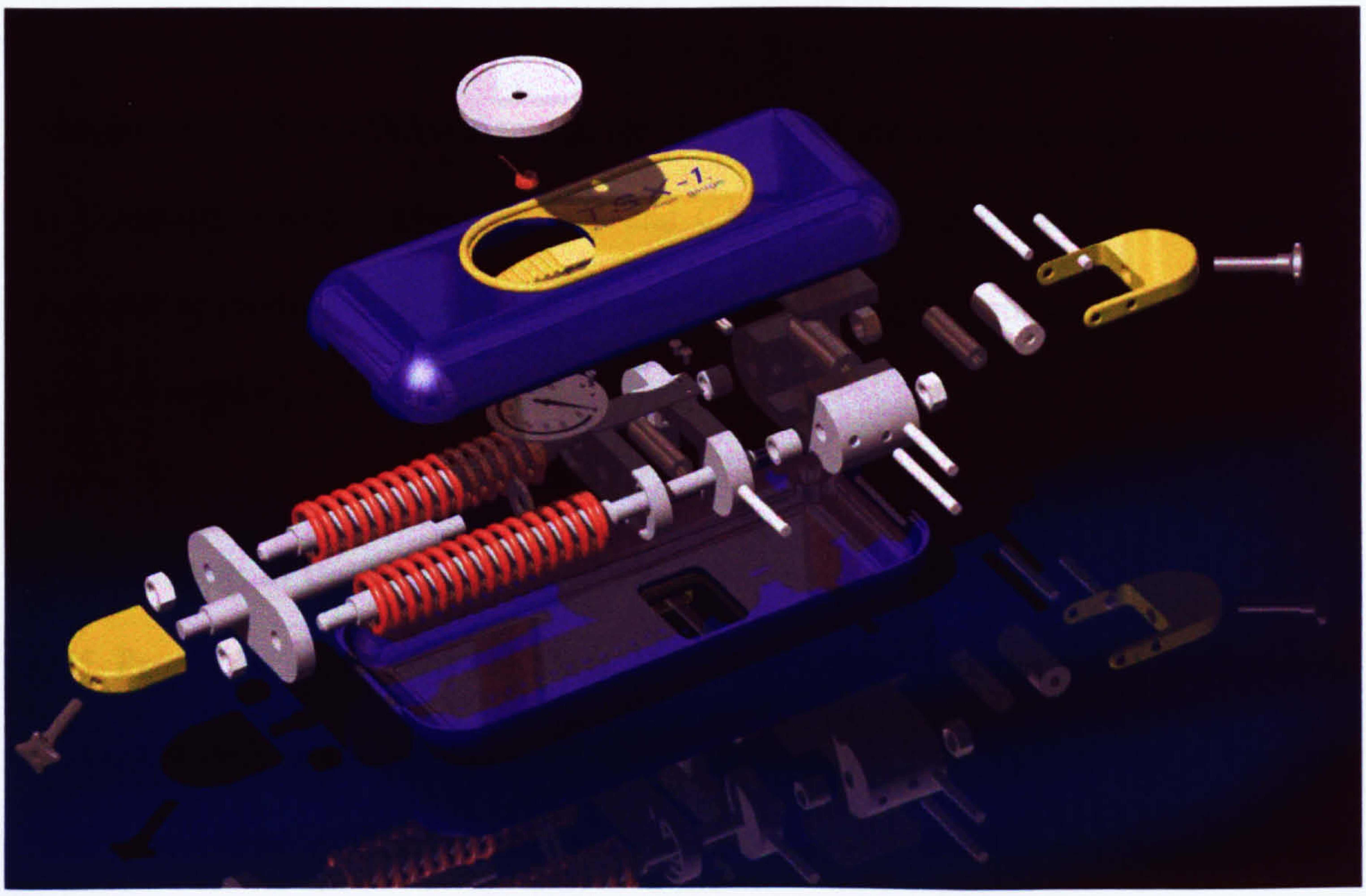


Plate 4.4 BSc CAPD Final Year Project. Cable Tension Gauge designed and produced by Chris Melia. Modelled in ProEngineer showing internal components and exploded view.



Q23. **Operate a CAD System for Surface Modelling.** Three companies (17.65 %) selected Very Good, four companies (23.53 %) selected Good, two companies (11.76 %) selected Competent, six companies (35.29 %) opted for Basic and two companies required no skill in this area whatsoever. The findings would indicate it tends to be a more specialised field used by a smaller number of companies when compared with 3D modelling systems.

It is the Author's opinion that surface modelling is an area where students have a limited amount of exposure when compared with other modelling and CAD systems and is therefore an area for development.

Q24. **Be able to use a Computer for word-processing, Reports, Charts etc**. Seen as a necessity in today's design industry. All companies required some level of knowledge in this area, three companies (17.65 %) selecting Basic, five companies (29.41 %) selecting Competent, four companies (23.53 %) selecting Good with the remaining five companies (29.41 %) requiring a high skill level of Very Good. These skills are introduced to BSc CAPD students in the first year of the course through modules such as Computer Aided Communications and CAD Fundamentals. All students are now expected to produce and present their assignments using this medium and many other forms of software.

4.7.6 Analysis of Design.

Q25. **Produce Calculations for Mass, Volume, Bending Moments and 2nd Moment of Area.** Most companies indicated they required a fairly high level of skill in this area. Three companies (17.65 %) selected Very Good, the highest percentage (47.06 %), representing eight of the companies, selected a skill level of Good with the other six companies equally split between Competent and Basic.

Q26. **Carry out Stress Analysis Calculations on a Component or product**. Three companies (17.65 %) required no skill level at all in this particular area, and when considering their product range of Electrical Installation Equipment, Bathroom Products, Speedometers and Tachometers it could be justified that this type of stress analysis would not play an important role.

Of the other companies, one (5.88 %) required a Basic knowledge, six (35.29 %) selected Competent, four (23.53 %) selected Good and the other three companies (17.65 %) a level of Very Good.

Q27. **Carry out FE Analysis on a Component or Product**. Similar statistics to Q26 but this time four (23.53 %) of the companies required no Level of skill in this particular area. Three companies (17.65 %) indicated Very Good as a level of skill requirement for their designers. Their product range included Cars / Off road vehicles, Flight Control Equipment and Products for Aerospace / Petrochemical Industries. Three (17.65 %) selected Good, Four companies (23.53 %) Competent and the remaining three companies (17.65 %) a Basic knowledge of Finite Element Analysis.

The following page shows a BSc CAPD assignment, using FE analysis software applied to a loaded Car Towbar.

Q28. **Use Ergonomics in the Design Process**. Only one company required no skill. Three companies (17.65 %) required Basic, three companies (17.65 %) Competent, six companies (35.29 %) Good and four companies (23.53 %) Very Good indicating the usage of Ergonomics in a wide product range. Introduced to 1st year students in modules such as Product Design and Development or Product Design Studies 2, students develop and make use of these skills throughout the course in their design assignments and projects.

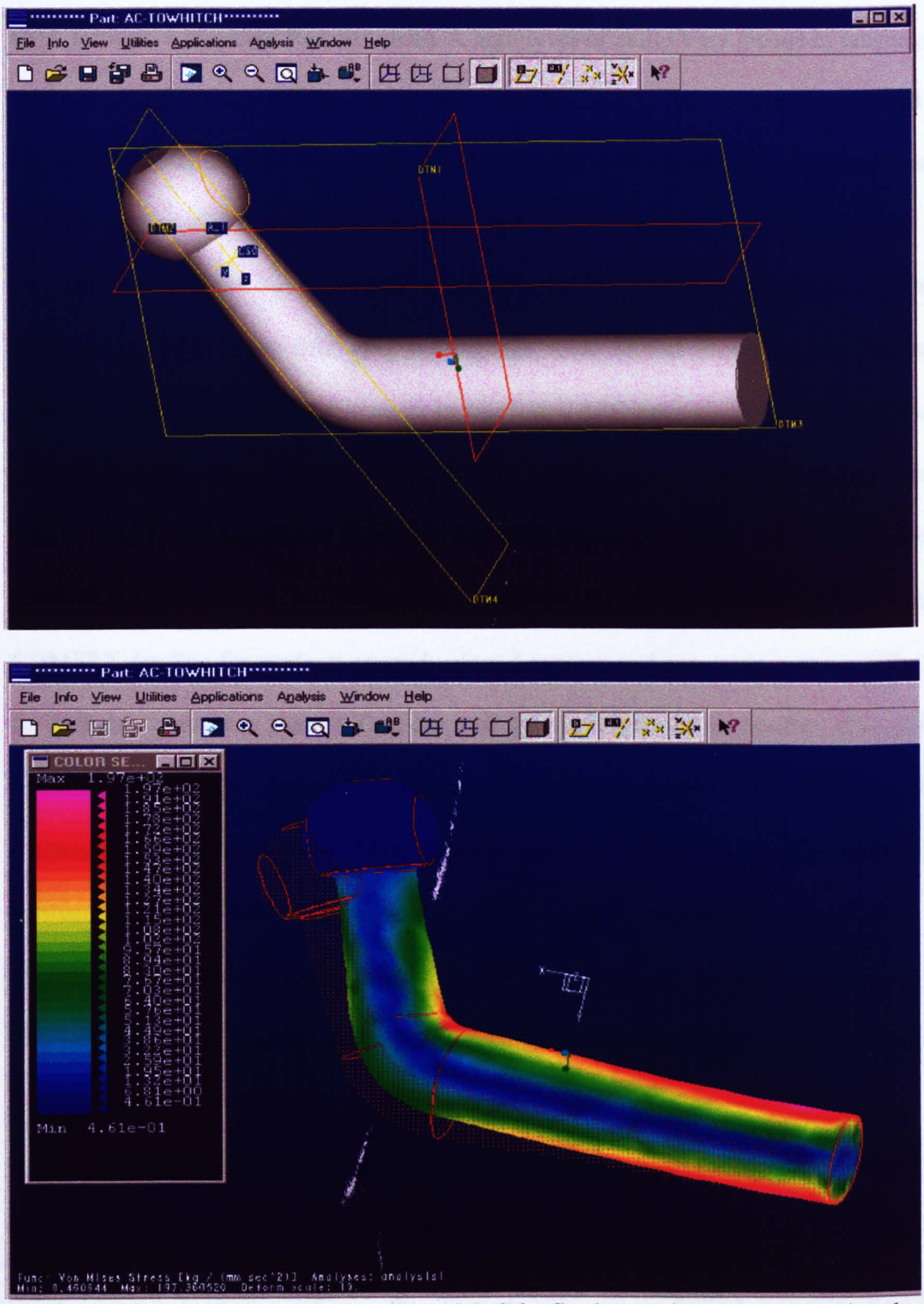


Plate 4.5 BSc CAPD Design Assurance Module. Student assignment to examine the behaviour of a loaded Car Towbar using Finite Element analysis. Top frame shows Towbar modelled in ProEngineer, bottom frame highlighting high stress concentrations in red and deflection using Finite Element analysis approach.

4.7.7 Business.

Q29. **Foreign Language Requirement.** A high level of skill (Very Good) in languages was not sought by any of the companies. Only two (11.76 %) companies required a Good level of skill in this area, three (17.65 %) required Competent, six required Basic and the other six (35.29 %) of companies no skill whatsoever.

The language options built previously into BSc CAPD never really became popular, with just a few students following a Language route option. However, this has not deterred students from studying abroad, in fact BSc CAPD have always had a good track record for the number of students studying or working abroad during their sandwich year. Countries have included America, Argentina, Finland, France, Germany, Greece, Holland, Hong Kong and Spain. As previously discussed, the ending of ERASMUS and COMETT funding for students to study abroad appears to have made it more difficult for students to travel to Europe. One can now see the decline in the number of students in industry placements abroad, even though LEONARDO and SOCRATES funding has replaced it. General figures from the International office at the University of Wolverhampton 1998/99 based upon students studying in Europe gave a ratio of 3 – 1 exchange i.e. three European students chose to study at the University of Wolverhampton compared with one University of Wolverhampton student studying abroad.

Q30. **Preferred language if applicable to Q29.** Only five companies responded to this. The most popular language was French which three companies selected, the companies in question involved in (new product development, nut and fastener tightening tools and products for aerospace / petrochemical). One company (cars and four wheel drive vehicles) preferred German and one company (bathroom products) selected Italian.

Q31. **Deal with clients.** Although 3 companies (17.65 %) required no skill in this area the remaining 14 companies gave positive responses, one company (5.88 %) indicated requiring a Very Good skill level, 9 companies (52.94 %) the largest % selecting Good and the remaining four companies (23.53 %) opting for a Basic skill level.

Q32. **Marketing.** All companies except one required some level of knowledge. One company (5.88 %) at a Very Good level, six companies (35.29 %) indicated Good, three companies (17.65 %) indicating Competent, with the remaining six companies (35.29 %) requiring just a Basic knowledge.

Q33. **Advertising.** Only a few companies required some level of skill in advertising. One company (5.88 %) required a skill level of Good, 3 companies (17.65 %) indicating Competent and six companies (35.29 %) just a Basic knowledge. Surprisingly (41.18 %) representing 7 companies required no knowledge of Advertising.

Q34. **Costing.** This was seen by all of the companies as a necessary requirement. Three companies (17.65%) required a Very good understanding. (52.94%) representing 9 companies required a Good understanding. Three companies (17.65%) selected Competent and the other two companies (11.16%) a Basic knowledge.

Q35. **Appreciation of the role of other departments within the company.** Perceived as a very important requirement by nearly all companies (company procedure) with 3 companies (17.65 %) selecting a Very good understanding, the majority 11 companies representing (64.71 %) selected a skill level of Good. Two companies (11.76 %) selected Competent and just one (5.88 %) selected Basic.

Q36. **Be able to plan a job.** From the companies responses this is seen as a very important attribute of a designer. Eight companies (47.06 %) required a Very Good level of skill followed by six companies (35.29 %) a Good level of skill, with two companies (11.76 %) Competent skill and one company (5.88 %) a Basic skill level. Introduced in year 1 in Product Design and Development, and seen as crucial in all design projects throughout BSc CAPD. A specific module Project Planning plays a very important role in the final year of the course in planning the major final year project.

Q37. **Work as a Member in a Design Team.** Obviously seen as a requirement and a very important quality in a Designer. A unanimous response by all companies requiring either skills related to Very Good representing 64.71 % of companies, and Good representing the other 35.29 % of companies. The BSc CAPD aims at developing these skills through out the course from year 1, making use of group design assignments, group seminars, and group presentations.

4.7.8 Manufacturing Methods.

Q38. **Knowledge of general processes:- casting, forging, presswork, welding etc.** The majority of companies required a Good knowledge (47.06 %), or Very Good knowledge (29.41 %) only two companies (11.76 %) required Competent, and the other two companies (11.76 %) required a Basic knowledge. These processes are covered in 1st year modules Product Manufacturing studies.

Q39. **Knowledge of material properties for steels and other metals.** Surprisingly two companies (11.76 %) required no knowledge yet six companies (35.29 %) required Very Good and another seven companies (41.18 %) Good, the other two companies (11.76 %) selecting Competent.

Q40. **Knowledge of material properties for Plastics.** The highest selection, representing (41.18 %) of companies, chose Competent, with (29.41 %) and (17.65 %) choosing Good and Very Good respectively. Two companies (11.76 %) required just a basic knowledge.

Q41. **Knowledge of Component Testing i.e. Tensile, Impact, Hardness etc.** The majority of the companies opted for Competent (35.29 %) or Good (35.29 %). One company required a Very Good knowledge with two companies (11.76 %) requiring just a Basic knowledge. The same two companies who selected no knowledge for *Q39* selected none again for this question. The level of skill for *Q38* to *Q41* correlated to the companies products i.e. usage and design in Plastics or Metals.

Q42. **Computer Aided Manufacture (CAM).** Twelve out of the seventeen companies selected Competent (35.29 %) or Basic (35.29 %). Three required Good (17.65 %) and one Very Good. One company required no knowledge of CAM.

Q43. **Robotics and Material Handling.** The bar chart indicated that no company required Very Good as a level of skill in this particular area, most opted for the lower end of the scale. Three companies (17.65%) required no skill, the majority, eight companies (47.06 %) required just a Basic knowledge with four companies (23.53 %) requiring Competent and only two (11.76 %) requiring a Good knowledge.

Q44. **An understanding of Electrical / Electronic systems.** A mixed response, one company (5.88 %) required no knowledge, six (35.29 %) required just a Basic knowledge and five companies (29.41 %) required Competent. Four of the companies (25.53 %) indicated a Good understanding, one (5.88 %) the Flight Control Equipment Company required a Very Good knowledge, as one would expect in this particular product field. Electrical / electronics is introduced in year 1 of BSc CAPD in Fundamentals of Technology 2 at an introductory level. Students can become more specialised in this field by choosing projects which fall into this category.

Q45. **An understanding of Pneumatics / Hydraulics.** Three companies (17.65 %) selected Very Good and one company (5.88 %) selected Good as a requirement in this particular area. These findings link directly to their company products of Power Tools, Flight Control Equipment, Aerospace/ Petrochemical and Mini Excavators. Five companies (29.41 %) chose Competent, six (35.29 %) just a Basic understanding. The remaining two (11.76 %) companies, Bathroom Products and Speedometers / Tachometers, required no understanding of Pneumatics / Hydraulics.

Q46. **Design for Manufacture.** Most companies, approximately 78%, indicated the importance and a high skill level requirement in this area for designers. Ten companies nearly 60 % indicated a skill level of Very Good with another three companies nearly 18 % selected Good. Three companies (17.65 %) chose Competent and one company Basic.

Q47. **Design for Assembly.** Again, similar findings to *Q46* with nearly 77% of companies indicating Design for Assembly as a very important aspect. Twelve companies (70.59 %) selected Very Good and one company (5.88 %) selected Good. Three companies (17.65 %) selected Competent in this area, with just one company (5.88 %) required a Basic knowledge.

Q48. **Knowledge of Stereolithography and Rapid Prototyping.** Two companies (11.76 %) required no knowledge of these techniques, seven (41.18 %) required just a Basic knowledge, five (29.41 %) selected Competent with two companies (11.76 %) selecting Good. Only one company required a Very Good knowledge. A surprising set of results for relatively new technologies. However, it is envisaged that, as these model-making techniques become more accepted due to the benefits of a reduced lead-time and a reduction in cost of prototypes, a good working knowledge of this technology will become paramount for the practising designer.

4.8 Companies' Comments Based Upon What Skill Levels They Feel Designers Are Lacking.

phd2\comments

The following listing has been compiled from the company survey on the recruitment criteria for design engineers and product designers.

Company Product	Q8. What skills do you feel designers are lacking ?	Q9. Any other comments.
1. Power tools and Electrical Appliances.	Commercial skills:- knowledge of wider business environment, basic appreciation of the supply chain, Marketing. Team working skills and operating in multi-functional environment.	Although I've ticked most boxes rather than tick some I've put a comment next to them, because I felt the issue is not a "Yes / No " one, but one which may have varying degrees of relevance or importance.
2. Cars / 4*4 Vehicles.	Drawing Skills.	None.
3. Flight Control Equipment.	Team working skills Rounded ability.	There difficult to find.
4. Electrical Installation Equipment.	Understanding mechanisms. Correct choice and appropriate use of materials. Major strengths / weaknesses of common plastics. Effect of environment on common materials especially plastics. Design parameters for active components i.e. springs / bi-metals. Nature of electric arcs on contacts and housing.	Designers should consider ERB (and professional institutions) as a must, but CEng is not essential. More work experience within the University course years would help the design of practical products that can also be manufactured.
5. New Product Development / Product Design.	Imagination :-ability to come up with good concepts. Aesthetic ability:- making things look good.	The two opposite cannot really be taught, but more effort should be made to bring them out whilst at University / College.
6. Nut and Fastener Tightening Tools.	On the job experience. Manufacturing methods (JIT,SMED, KAIZAN etc.)	None.
7. Locks.	Communication generally, but report writing in general. (standard of English appalling) Often seem lacking in practical skills, knowledge of manufacturing processes etc. Do not often see true creative ability or ability to think laterally essential skills for designers , but how do you teach them ?	I have based my replies on product designers generally, obviously for newly qualified designers we would expect younger candidates with less work experience, in which case we would probably look for higher qualifications e.g. HNC / HND as an indication of abilities generally, in the absence of a good work record.

8. Bathroom Products.	None	Many students lack appreciation of the role of design and its relationship with other departments.
9. Vans and Pressings.	Lack of an enquiring / challenging mind. Project management skills. Automotive design understanding, particularly Electrical / Legislation / Timing. F.M.E.A . plus design verification planning. Marketing and understanding customers needs.	CAD training on major systems could be carried out at university e.g. IBM CATIA, CADD5X, etc. = guaranteed jobs for graduates. Very few Universities offer Automotive sector product design expertise and no University offers Automotive electrical design.
10. Mechanical Design for the Automotive Industry.	Experience of working in a non academic environment. Working to target dates. Time management. Knowledge of manufacturing methods.	None.
11. Showers and Mixer Valves.	Interpersonal skills :- presentation, communication , influencing, report writing , project management.	None.
12. Mini Excavators	Basic Engineering skills and the 'feel' for components, i.e. bolt sizes, plate thickness, size of weld required, tolerances. Also the capability of processes, including tolerance and surface finish. Cost Vs finish Vs requirement	The answers given reflect the fact that we use a 2D CAD system and the product has a majority of fabricated components. I feel that the other main company would give different answers due to their 3D CAD system. The questions about membership of a professional body do not give a true picture of our company. We do not actively encourage membership, but would look favourably at anyone with membership. Regarding professional development we do train our staff in any area which is felt to be a benefit for their career. This would include technical courses, managerial and personal training. I have purposely not used the 'very good' box, because I think this is for a specialist skill and not a general design position.

13. Fire Resisting Diskette Cabinets.	An awareness of the customer and business acumen, the need for product quality, reliability, zero complaints at minimal product cost, marketing objectives and products at minimum cost. Designers need to be fully integrated into the manufacture and production engineering environment. They have no idea of the bottom line , budgets and profit.	I have a total preference for in house trained company apprentices who have grass roots experience. I would not recruit college bred students who do not have any or complimentary industrial experience. We monitor our apprentices and recruit those with relevant potential. We cannot afford passengers.
14. Speedometers and Tachometers.	Practical experience. Ability to put ideas into practice. Ability to plan accurately.	General lack of knowledge in electronics due to diversity of components and suppliers, also due to rapid integration of IC's.
15. Office Equipment.	Range of CAD type experience. Knowledge of electro-mechanical industry.	Depending on position available we take people with no design experience and train them , otherwise we need competent staff at all times.
16. Bus and Coach bodies.	Practical , hands on experience.	None
17. Products for the Aerospace and Petrochemical Industries.	Practical basic engineering skills such as hands on knowledge of welding, metal forming, maching etc.	None

4.9 Company Questionnaire, Conclusions And Findings.

4.9.1 Educational background

The findings would confirm the Author's opinion that most companies would consider for employment young Product Designers under 25 years of age who are qualified to HNC, HND or Degree level and preferably with some industrial experience but not necessarily higher degrees, MSc or PhD. This allows the companies to train and mould young designers in company procedures and their product range. One company makes the specific comment that "for newly qualified designers we would expect younger candidates with less work experience, in which case we would probably look for higher qualifications e.g. HNC / HND as an indication of abilities generally, in the absence of a good work record".

A stigma appears to be attached to higher degrees, the person being considered research orientated and often quoted as being "too qualified for the post". [3]Nwagboso et al (1998, p120) makes reference to similar findings within the Automotive industry "Automotive vehicle manufacturers do not like to hire graduates with a PhD degree". General reasons put forward by Nwagboso et al are that some companies consider PhD students as thinking they are something special and tend to be less co-operative with their employers when told what to do.

A very small percentage of companies indicated a preference for their designers to have "grown up" with the company i.e. initially taken on as apprentice or technician, studied at a College of Further Education then onto Higher Education, but these are now few

[3] NWAGBOSO, C. and FIJALKOWSKI, T. (1998) *Developing An Academic Discipline In Automotive Mechatronics.* Proceedings: Edukacja W Mechatronice, Academia Gorniczo-Hutnicza, 12-13 Oct 1998, Cracow, Poland p.120.

and far between. One Company representative had particular strong feelings towards this, commenting " *I have a total preference for in house-trained company apprentices who have grass roots experience. I would not recruit college bred students who do not have any or complementary industrial experience. We monitor our apprentices and recruit those with relevant potential. We cannot afford passengers*".

Regarding new designers obtaining graduate membership of a professional body and further progression to becoming a Chartered Engineer once working for the company, statistics showed the majority of companies indicated this was not important, 80% in the case of graduate membership and 70% of companies for Chartered Status. Two companies made specific comments to membership of a professional body, the first company stated "*The questions about membership of a professional body do not give a true picture of our company. We do not actively encourage membership, but would look favourably at anyone with membership*" and in the second case "*Designers should consider professional institutions as a must, but CEng is not essential*".

Clearly the benefits of membership and becoming a Chartered Designer/Engineer in the UK are at present limited. It carries less status than our counterparts in Europe or other professions such as Medicine and this should be a concern for the Engineering professional bodies. In nearly ten years of interviewing prospective students for BSc CAPD courses the Author has only been asked once if the course leads to Chartered status.

4.9.2 Work Experience

A large percentage of companies from the survey (nearly 65 %) stated work experience was essential with the area of work experience also playing a significant part in selection.

In the past Industrial placements have played an important role for BSc CAPD sandwich students who have gained valuable experience and positions in the company when graduating. However, the ending of ERASMUS and COMETT grants have seen the number of BSc CAPD students studying abroad diminish even though these schemes have been replaced by SOCRATES and LEONARDO funding. The introduction of student fees in 1998 may now make it more difficult for many students to take the opportunity of working and gaining experience in a company within the UK or abroad because of the financial implications. An increasing number of students now want to finish their degree as soon as possible with minimal cost. More are living at home to reduce costs further, and fees during the placement year are seen as yet another financial burden unless the placement company is willing to sponsor the student and pay the fees. Early indications from the BSc CAPD course show the lowest number of completed second year students entering work placements in October 1999, approximately 14%.

Exposing students to 'live' company-based projects and National Competitions in modules may be one way of alleviating this problem. This practice has been encouraged throughout the BSc CAPD curriculum but is by no means a substitute for industrial experience. Some graduates find themselves in a "Catch 22" situation, they need work experience to get employment, but they need employment to get the work experience.

The statistics from the survey highlighted 94 % of the companies placing an importance on continuing professional development for staff once in the company to update their skills, which is paramount in today's rapid changing market. One Company makes specific reference to this "*Regarding professional development we do train our staff in any area which is felt to be a benefit for their career. This would include technical courses, managerial and personal training*".

4.9.3 Manual Drawing Board Ability and Communication Skills

Most companies in the survey expected design graduates to be able to produce good design sketches/diagrams, read/interpret engineering drawings and produce part/detail drawings and in particular be able to think in 3D.

It is the Author's opinion that teaching drawing skills on a manual drawing board is a thing of the past and is better taught using CAD because of its speed and flexibility. An analogy to this is the teaching of Log Tables when Scientific Calculators were introduced. However, good sketching techniques and producing the initial design ideas by hand are still very important communication skills. This concept is increasingly more difficult to get across to students who invariably wish to sit at a computer and design from the offset. Findings from final year modules, such as Design Competition and Projects have indicated that designs can often be identified as being designed by computer due to primitives that have been used in building the 3D model, and design flair is restricted in some cases.

Students studying the BSc CAPD are given the chance to acquire physical modelling and prototyping skills. These are developed in modules such as Product Manufacturing Studies, Product Design and Development in the first year, Design Practice and 3D Realisation in the second year, Design Enterprise Studies and the major project in the final year. The development of Rapid Prototyping techniques for prototype models has already been accepted and used by BSc CAPD students, making use of CAD model data from their final year projects; the use of foam, wood and card thus relegated to quick sketch models. One may ask why teach students these traditional modelling skills? The students obtain the concept of physical size and actual measurement of the product that a CAD system cannot give them, along with a feel for the Ergonomics and Anthropometrics data associated with the model. Aesthetics, tactile and visual perception in 3D are also very important although 3D CAD modelling systems are becoming increasingly refined in helping the designer in this respect.

4.9.4 Use of Computers in Design

The findings indicate that virtually all the companies require Designers with a high level of skill in this area.

Operating a CAD system for 2D and 3D modelling has always formed a significant part of the learning experience in many of the modules for students studying the BSc CAPD course. From an introductory level at year 1 up to a competent level by year 2 and fairly advanced level by the end of the final year. The benefits again are the number of graduates obtaining employment in this particular field and commanding good salaries. This is highlighted by a small number of students who on completion of their placement year have elected to stay with the company purely on financial grounds and study the final year on a part time basis. In most cases experience has shown that few students in this situation actually complete their degree. One Company backs up these findings with the comment "*CAD training on major systems could be carried out at university e.g. IBM, CATIA, CADD5X, etc. = Guaranteed jobs for graduates*".

The growth in Media Technology for communication and presentation techniques is becoming more sophisticated and readily available. BSc CAPD students are encouraged to utilise these modern multi-media skills in communicating their design and marketing their products. Students produce 3-D computer generated models and run animations of their design, transferring these to video or CD-ROM with backing sound tracks. Virtual reality software can be used to show these models from any viewpoint or actually enter the inside of the product to see its functionality. An example may be travelling through the inside of a video player or engine/gearbox looking at the 'internals' to discover if there is any interference of parts.

In its infancy it was often stated that "Virtual Reality is a solution looking for a problem".

[4]Hartley (1992, pp.191-192) comments upon "Virtual reality opening up a golden era" and "as computer power increases, so virtual reality (VR) will be adapted to product design to provide a super CAD System."

The developments in Virtual Reality software and the added dimension of holographic design using computers will play an increasing role in product design in the future. [5]Eisenstein (Jan 1999 article) discusses the use of holographic images by the Ford Motor Company at the North American International Automotive Show to view their P2000 prototype car. The displayed prototype was a half size of the car produced as a 3D hologram projection generated from engineering data and digital design. The system gives Ford the ability to use computer-generated images to create the hologram. A variety of uses are put forward in the article by Tom Scott, Ford's director of advanced design at that time "designers and engineers could create holographic models, saving building prototypes out of wood, metal or clay. Corporate decision-makers might use these to choose from several proposals". The article concludes, " It is also working on ways to project holographic images right out of the computer. This would allow employees to sit at 3D Workstations. And using special haptic gloves, they could

[4] HARTLEY, John. (1992) *New Product Design for World Class Markets, The management guide.* MORTIMER, J. (ed.) Industrial Newsletters. Dunstable, Beds: Publised in association with the Dti as part of the Managing in the '90s' programme, pp.191-192.
[5] EISENSTEIN, P. (13[TH] Jan 1999) *An added dimension to design* UK: Professional Engineering, Vol 12 No 1, p.32.

interact with the image. A stylist might, for example take a design and reshape it, much like a piece of virtual clay".

Further uses in holographic technology are proposed in an article in the [6]Eureka Journal of Innovative Engineering Design (Summer 1999). It discusses a company, Zebra Imaging, who aim to develop a desktop unit over the next two years for use in design or marketing purposes. Ford motor company sees the possibility of usage extending to simulating car crashes and other events in which design is crucial.

4.9.5 Analysis of Design

The majority of companies required designers to have a fairly high level of skill in producing basic design calculations. Modern design software packages increasingly compute most of the calculations for the product designer, items such as Mass, Volume, Centre of Gravity, 2nd Moment of Area, and FE analysis etc can be obtained at the stroke of a key, the difficulty is making the students question these results rather than just accepting them as correct. A problem appears to be the poor standard of mathematics ability that students have when they enter University. Extra tutorial support in year 1 and CAL software have been introduced to alleviate this problem.

The companies responses to designers being able to produce Stress Analysis calculations and using FE Analysis on a component was mixed and would suggest that the type of product and its working environment dictate its specialist usage. All BSc CAPD students use these techniques and have some working knowledge of FE Analysis software, which form a significant part of their assessment in a number of modules throughout the course.

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[6] Eureka on Campus, Innovative Engineering Design. (Summer 1999), *Holograms go for the big picture with cars.* Kent: Findley Publications Ltd, p.4.

4.9.6 Business

The companies responses were regarding various business skills. A number of companies indicated some Foreign Language knowledge being of benefit to the company, the most popular being French. The language requirement linked directly to the company export product i.e. Italian for bathroom products and German for automotive products.

Most companies expected students to be able to deal with clients, a skill requirement readily gained by Sandwich degree students when in a company on placement. This environment is more difficult to achieve for full time students however; communication skills in a number of modules are an attempt at alleviating this and provide the opportunity for the student to gain the confidence to deal with this situation.

Knowledge of marketing was perceived as a necessity by nearly all of the companies concerned, but only a few indicated requiring any knowledge in advertising when recruiting new designers. These skills are developed in modules such as Design Practice and Design Enterprise Studies where students are required to design and develop a new product and in the case of Design Enterprise studies, provide a marketing plan concluding with a group presentation or seminar using video or CD-ROM media format.

All companies saw costing as an important skill requirement. BSc CAPD students are required to produce costing as part of the assessment in most of the "design and make" assignments, design competition and project. This may take the form of profit, development, prototyping, tooling, material and manufacturing costing.

Companies saw appreciation of the role of other departments within the company as an important acquisition; again sandwich students gain this experience from their placement but it is a difficult environment to simulate for full time students.

From the companies responses, planning a job and working as a member in a Design Team was seen as very important qualities in a Designer, the BSc CAPD aims at developing these skills and encourages them throughout the course in a number of modules.

Business Studies, Business Enterprise and a Foreign Language when introduced as separate option routes within the BSc CAPD course never became popular, only a minority of students (one or two) specifically requesting this option. However, the business side to Product Design is seen as an increasingly important requirement when attempting to promote and market new products. To this effect aspects of business are built into a number of modules, in particular the level 3 module Design Enterprise Studies as previously discussed. Feedback from final year BSc CAPD students is very positive towards this module.

4.9.7 Manufacturing Methods

All BSc CAPD students cover basic manufacturing processes in the first year module Product Manufacturing Studies 1, which forms the foundation for further processes and manufacturing techniques in subsequent modules.

In general most companies required a good knowledge of general manufacturing processes such as casting, presswork etc. Knowledge of material properties for steels, metals, plastics and component testing by the companies was mixed, indicating the level of skill dependent upon the company product range. Most companies required knowledge of CAM yet few mentioned robotics and materials handling.

The majority of companies perceived the contemporary areas of Design for Manufacture and Design for Assembly playing an important role with a high level of skill requirement for their designers in both of these areas. However, little knowledge was expected of the techniques behind Stereolithography and Rapid Prototyping as tools used in the design to manufacture process. As previously discussed under (Manufacturing Methods Q48) Stereolithography and Rapid Prototyping techniques are becoming well established because of the reduced lead time and reduction in the cost of prototypes, therefore a good working knowledge of these processes will be paramount for the designer. Because of their usefulness to the designer, these techniques have been introduced into the BSc CAPD curriculum from the outset.

4.9.8 What Skills Do You Feel New Designers Are Lacking?

The following observations were based upon the companies comments as tabled under the heading: - (4.8 Companies' Comments Based Upon What Skill Levels They Feel Designers Are Lacking). Where similar comments have been made by a number of the companies these have been grouped together. The companies comments appear in Italics and have been categorised under the five listed headings: -

- Practical Experience, Manufacturing.
- Communication, Drawing Skills, CAD Related Skills.
- Business.
- Team Working Skills.
- Creative Ability.

4.9.8.1 Practical Experience, Manufacturing.

"Practical experience".

"Practical hands on experience".

"Practical basic engineering skills such as hands on knowledge of welding, metal forming, maching etc".

"Basic engineering skills and the 'feel' for components, i.e. bolt sizes, plate thickness, size of weld required, tolerances. Also the capability of processes, including tolerance and surface finish".

"Often seem lacking in practical skills, knowledge of manufacturing processes etc.".

"Manufacturing methods (JIT, SMED, KAIZAN etc.)".

"On the job experience".

"Experience of working in a non-academic environment".

"More work experience within the University course years would help the design of practical products that can also be manufactured".

"Correct choice and appropriate use of materials". "Major strengths / weaknesses of common plastics". "Effect of environment on common materials especially plastics".

"Design parameters for active components i.e. springs / bi-metals". "Nature of electric arcs on contacts and housing".

"Understanding mechanisms".

"Knowledge of Electro-mechanical industry".

"General lack of knowledge in electronics due to diversity of components and suppliers, also due to rapid integration of IC's".

The findings would indicate that a large number of the companies comments were directly related to students graduating and lacking practical experience, having little hands-on experience and knowledge of manufacturing processes and material properties. A number of the companies made reference to students lacking on-the-job experience, and experience of working in a non-academic environment. In many ways practical experience and job experience are directly linked.

The UK has seen the number of apprenticeships decline in most companies over a number of years due to the rationalisation of the workforce, hence valuable practical experience and engineering skills are being reduced. We are now faced with the possibility, due to fees and financial commitments imposed upon students, that the number of sandwich students entering work placement may decline, compounding this problem. One way of assisting sandwich students would be too waive the fees during the placement year or provide a tax incentive for the company to take on these students and sponsor them. The pessimistic view is that the sandwich degree programme may become a thing of the past along with its valuable contribution to practical, social awareness skills, work ethic and job opportunities.

Colleges and Universities must strive to include as much practical experience as possible within their courses. However, there is no real substitute for working within a company environment where these skills can be fostered, especially when the company is using state-of-the-art equipment, specialised manufacturing processes and materials or practising modern manufacturing methods e.g. Japanese philosophies and working practices of Just In Time (JIT), Kaizan, Kanban etc.

The effect of product design and the impact of materials such as plastics on the environment are a growing issue for designers, both from the legislative point of view and peoples perceptions of a need for recycling. [7]Simon (1991) discusses recycling under the heading 'Design For Dismantling' and opens his paper by highlighting the fact that countries such as Germany are already considering legislation to force manufacturers to take responsibility for the disposal of their products. Undoubtedly the rest of Europe and the UK will have to follow suit. Simon (1991) makes the statement

[7] SIMON, Matthew. (November 1991) *Recycling, Design For Dismantling*. UK: Professional Engineering, pp.20-22.

"In future, the design of motor vehicles and many other products will have to take greater account of what happens at the end of their lives. Deliberate design for dismantling is one way of assisting the product to conform to environmentally sound principles".

Product Design courses need to address these issues with modules covering the life cycle of the product from conception to retirement and its impact on society. Design for Manufacture, Design for Recycling, Design for Assembly / Disassembly, where importance is placed on reducing the number of parts-count in the product, and Packaging Design and how the packaging is disposed of or recycled will all play a major role in the design process in the future.

4.9.8.2 Communication, Drawing Skills, CAD Related Skills.

"Communication generally, but report writing in general. (Standard of English appalling)".

"Interpersonal skills: - presentation, communication, influencing, report writing".

"Drawing Skills".

" Range of CAD type experience".

"CAD training on major systems could be carried out at University".

It is a fact that the standard of written English is poor amongst some students on entering University even though these student have gained an appropriate qualification in the subject. In the majority of cases this improves during the course as students are subjected to communication presentation techniques, word-processed assignments with spell check, project dissertations and oral presentations within modules where these core skills are built into the learning outcomes.

Basic drawing skills and sketching techniques are limited for a number of students who enter University unless the student has come via an Art and Design or Engineering route. Less emphasis appears to be placed on these skills during school years with Craft Design and Technology having a wide and varied syllabus i.e. Food Technology, Graphics, Construction, Textiles, and Electronics, with more emphasis placed on the Information Technology skills. Although 2D drawing can be taught by using CAD many students lack the ability to produce good quality design sketches at the concept stage. This has been recognised by the course team on the BSc CAPD and needs to be included and developed further in more of the modules.

CAD has always played a significant role in the BSc CAPD course, providing a varied range of CAD experience with CAD training on the major systems, thus providing students with excellent employment prospects.

4.9.8.3 Business.

"Commercial skills: - knowledge of wider business environment, basic appreciation of the supply chain, marketing".

"Project management skills". "F.M.E.A plus design verification planning".

"Marketing and understanding customers needs".

"Working to target dates".

"Time management".

"Project management". "Cost Vs finish Vs requirement". " An awareness of the customer and business acumen, the need for product quality, reliability, zero complaints at minimal product cost, marketing objectives and products at minimum cost". "They have no idea of the bottom line, budgets and profit". "Ability to plan accurately".

Practising product designers are fully aware of working to target dates, time management and project management skills and likewise these play a significant role during the BSc CAPD course. All students work to target dates in completing and handing in projects or design assignments, and project management is progressively increased throughout the course, with a complete module Project Planning dedicated to this in the final Year of the course.

Failure Mode and Effect Analysis (F.M.E.A) plus design verification planning was mentioned, the final year module Design Assurance covers this specific aspect to design for BSc CAPD students.

Companies did, however, highlight a number of skills, which they thought students lacked. It could be argued that these skills could only be fully acquired once in a company. Marketing was mentioned by a number of companies; although students achieve marketing skills in modules such as Design Enterprise Studies many companies operate different marketing strategies. Likewise one company states "*Cost Vs finish Vs requirement. An awareness of the customer and business acumen, the need for product quality, reliability, zero complaints at minimal product cost, marketing objectives and products at minimum cost. They have no idea of the bottom line, budgets and profit*". Product design students at University understand the need for product quality and reliability, but some of the costing is more difficult to assess and can only be achieved once they are given an actual budget and the profit margin to work from.

4.9.8.4 Team Working Skills.

"Team working skills and operating in multi-functional environment".

"Team working skills, rounded ability".

"Many students lack appreciation of the role of design and its relationship with other departments".

"Designers need to be fully integrated into the manufacture and production engineering environment".

It can be seen from the comments made above that some of the companies identified students as lacking a number of specific team-working skills. Comments made such as "*many students lack appreciation of the role of design and its relationship with other departments*", "*operating in multi-functional environment*" and "*designers need to be fully integrated into the manufacture and production engineering environment*" confirm the author's opinion that designers of today need to adopt the 'integrative philosophy' of concurrent, simultaneous and parallel engineering concepts. Companies with specialised personnel attached to the product team, i.e. concept designer, engineering designer, manufacturing, prototyping, tooling, marketing and sales, can adopt and introduce this 'integrative philosophy' for new products. However, this is often a difficult environment to fully simulate or replicate in University.

[8]King et al (1995) discusses the Integration of Undergraduate Engineering Through Total Product Design (TPD) and its benefits. The Philosophy of the TPD final year module put forward by King is "to get students involved in real, open-ended, industrially based projects. These projects are intended to graduate the students with the necessary skills to work as effective professional engineers upon their first appointment". "TPD is a team based activity with students working in groups of five.

[8] KING, P. D and PRESTON, M.E. (10^{th}- 11^{th} July 1995) *Integration Of Undergraduate Engineering Through Total Product Design.* Proceedings of The 2^{nd} National Conference on Product Design Education. Coventry University, UK.

This emulates the real world-engineering environment where team activity is the norm as opposed to individual academic exercises, designed for ease of assessment".

First year BSc CAPD students are introduced to the integrated philosophy approach to product design through concurrent / parallel engineering concepts, and the important relationship between the design team and other key personnel, such as, manufacturing and marketing departments. The curriculum has been designed to enable students to work in groups on a number of design projects throughout the course to help foster the team-working approach. In particular, modules such as Graphical Modelling and Design Practice in the second year and Design Enterprise Project in the final year were designed to encourage this. Industrial based assignments and projects have played an increasing role in achieving this. Companies have provided sponsorship through prize money to students for the most appropriate designs and money to the department for equipment or software. Projects set up with companies by the Author have included the following: -

- Design of Tote boxes for both stacking and nesting.
- The external design of a Lorry cab.
- Design of tower boots for builders, electricians etc. A type of stilts up to a metre in height that are fixed to the feet to enable you to work overhead at an elevated level.
- Design of a locking mechanism for UPVC windows.
- Design of a top of the range bathroom accessories for four/five star Hotels and exclusive department stores.

Working on this type of 'Live' project enables the students to acquire skills in concept design, analysis, manufacturing, prototyping, marketing etc and thus take on these roles whilst at University. This gives students more flexibility for employment and equips them with some of the necessary skills to be able to communicate with the specialised personnel involved in a company's design team, as previously discussed.

For students pursuing a higher degree at the University of Wolverhampton this integrated philosophy is then further developed on what was the MSc in Engineering Product Design now revalidated as the MSc in Computer Aided Engineering Design course.

4.9.8.5 Creative Ability.

It was felt that due to the responses made by the companies to this particular area of creative ability and the vital role creativity plays within the design process the following chapter should be dedicated to this.

Chapter 5

5.0 Creativity And Innovation

The Oxford dictionary defines 'creativity' as having the ability to create things, inventive, showing imagination and originality as well as routine skill where as 'innovation' refers to introducing something new, bringing in novelties or making changes.

5.1 Companies Comments On Designers Creative Ability

A number of the companies who took part in the questionnaire commented upon designers often entering the profession lacking skills that could be allied to creative design. These company comments appear in Italics: -

"Do not often see true creative ability or ability to think laterally essential skills for designers, but how do you teach them?"

"Lack of an enquiring / challenging mind".

"Ability to put ideas into practice".

"Imagination: -ability to come up with good concepts". "Aesthetic ability: - making things look good". The Company felt these two aspects of design could not really be taught but more effort should be made to bring them out whilst at University / College.

A number of the companies recognised creativity, or design aspects relating to creativity, as being one of the most difficult areas to teach, yet it is being sought after by more companies as they strive to develop new ideas into products and keep ahead of the opposition. It would appear that there are a number ways of obtaining creativity: -

- Use an outside design consultancy or agency to develop new product concepts.
- Wait for other companies or people to develop the ideas / products and then buy them, adopt them, copy them, or use them as inspiration.

- As a company employ creative people, this could be an important policy to consider when taking on new staff. Also give existing creative staff encouragement and opportunities.
- Train people to be more creative.

Many companies use the first two methods for obtaining new ideas, concepts and product designs. The use of design agencies allows creativity to be bought when and where it is needed. When another company or person develops new ideas or products we have seen buy-outs of that company by other companies, or designs are copied, borrowed and modified. However, these methods have the disadvantage of not fully using the experience of existing staff within companies.

5.2 Developing Design Creativity / Innovation

Creativity has often been associated with invention, design and innovation. [1]Roy et al (1986, p.5) stated "Invention, design and innovation are frequently confused because all are creative activities. Invention and innovation, however, normally involve a technical advance in the known state-of-the-art of a particular field. Design normally involves making variations on that state-of-the-art".

[2]Cox et al (1991, p.1) in his introduction states "Many solutions, particularly the really innovative ones, seem in hindsight to be so obvious and simple, we often wonder why we didn't think of them. The answer lies partly in our own thinking processes and approach to problem solving. We all have the ability to be creative, if only we allow ourselves to be". The lack of development of new ideas put forward by Cox et al (1991)

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[1] ROY, Robin and WIELD, David, editors. (1986) *Product Design and Technological Innovation.* Milton Keynes, UK: Open University Press, p.5.
[2] COX, Geof., DUFAULT, Chuck., and HOPKINS, Walt. (1991) *50 Activities On Creativity And Problem Solving.* England: Gower Publishing Company Ltd, pp.1-3.

has often been associated with the way we are taught at school and how we build on this foundation and process information through life. The mind sets up sections, therefore patterns of thinking or processing information become set with time i.e. routines are established. These are essential in solving the majority of problems of every-day life, but they can prevent the development of new ideas.

Similarly [3]Hurst (1999, p.32) states "In general, education systems, right from the earliest stages, encourage conformity and discourage creativity and invention".

5.2.1 Lateral Thinking and Vertical Thinking

Figure 5.1 shows the two types of thinking and technical terms that are often associated with each. Dr Edward de Bono is the originator of the lateral thinking method, which is classed as a conceptual tool used to enhance creative thinking. [4]De Bono (1997, p.50; p.64) discusses how he thought of the term 'lateral thinking' in 1967 as a way of describing the sort of thinking concerned with changing perceptions and concepts. He describes lateral thinking as to do with change, especially when change involves escaping from a pattern within a patterning system. In ordinary terms the ability to look at things in different ways.

Lateral thinking or creative thinking requires imagination and leads to many possible answers or ideas. Lateral thinking is divergent, starting from the description of the problem and diverging to give many ideas or possible answers for solving it. It requires a wide-ranging examination of all the options, including what may be considered wild, foolish or which appear outside and not linked to the problem.

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[3] HURST, Kenneth, S. (1999) *Engineering Design Principles*. London: Arnold, p.8; p.32; p.33.

[4] DE BONO, Edward. (1997) *de Bono's Thinking Course revised – updated*. London: BBC Worldwide Publishing,p.50; p.64.

LATERAL THINKING (CREATIVE)	**VERTICAL THINKING (ANALYTICAL)**
IMAGINATION	LOGICAL
Generate many ideas or possible answers	Few ideas generated or unique answers
DIVERGENT	**CONVERGENT**

Fig 5.1 Two Types of Thinking

Vertical or analytical thinking is logical and leads to unique or few answers which can be implemented. This type of analytical thinking is convergent narrowing down to a small number of ideas or unique answers to identify all aspects that can be further analysed and implemented.

Although the two types of thinking are different they are linked because one type often complements the other. This is shown in creative thinking where the many ideas must be analysed to sort out the few that can be implemented. Analytical thinking consolidates ideas but often requires creative leaps to make progress.

Many lateral thinking techniques have been developed and published by Dr Edward De Bono over a number of years for various situations. However, [5]De Bono (1993, pp.201-212) applies lateral-thinking techniques to design as follows: -

The use of the lateral thinking techniques of Challenge, Escape Provocation, Concepts, Alternatives, Stepping-Stone Provocation and the Random Word are listed.

- Challenge. The creative challenge can be applied to a new design or a product that already exists, it is important at the start to challenge the usual approach to design; the definition of the problem can even be challenged. As the product develops, challenge the ways things are going, assumptions made and dominating concepts. Questions such as "why do we have to do it or look at it in this way?" "Why do we work within these boundaries?" Even formed ideas and designs can be challenged.
- Escape Provocation. Escape from the traditional design assumptions. Attempt to escape from the initial thinking of the designer who is faced with the design task, this can set off a new thinking direction. In design there are many normal things we take for granted. In the case of a computer we take for granted it has a keyboard and

[5] DE BONO, Edward. (1993) *Serious Creativity; Using the Power of Lateral thinking to Create New Ideas* London: HarperCollins Publishers, pp.201-212.

a mouse. Provocation would be to say the new design of computer would not have a keyboard or mouse, the new thinking of ideas such as touch screen, voice recognition may come about.

- Concepts. At the start of the design process the designer may be playing around with concepts and during the thinking process there is a need to explore ways of carrying out the concepts which can lead into the next phase of alternatives.
- Alternatives. The search for alternatives is the essence of creativity and can be used at many levels within the design process. Developing a concept during the creative thinking stage, the designer can look for alternative ways of carrying through the concept. Alternative approaches to the whole of the design or alternatives of implementation i.e. what materials, what colour can be used here? and alternatives to detail within the overall direction of the design.
- Stepping-Stone Provocation. The analogy comes from crossing a stream, the first approach may be to test the depth of water using a stick, and the second is to use the stepping-stone to get across. There are two operations, setting up the stepping stone then using it. This is a useful provocation technique for developing radical new approaches by turning the problem inside out and categorising things in a new way. This can be at the beginning in order to provoke a totally new design concept.
- The Random Word. This is useful in design in order to overcome complacency. Often a design concept emerges early and can trap further thinking on the matter; this can be difficult to get away from. A random word can suddenly open up a whole new concept. The random word may be generated by brainstorming or other techniques that are discussed later in this chapter.

5.2.2 Creative Process Model

With reference to Figure 5.2 many writers put forward this linear model of the creative thinking process. The first part involves recognising a problem exists and setting about solving it. In product design this may not be entirely clear initially and formulation of the problem may be a critical phase.

Preparation requires developing an idea or ideas for solving the problem. As the problem is re-formulated there may be many times when movement between stage 1 and stage 2 is carried out.

This often-hard work is followed by stage 3, incubation with no apparent effort, a time-out period. Often you sleep on the problem to give the preconscious mind a chance to operate.

Stage 4 illumination is the sudden emergence of an idea often unexpected, this is similar to suddenly remembering a name, face or place that could not be recalled when it was previously required.

The final stage 5 verification is where the idea is tested and developed.

Creative problem solving may involve either individuals or groups. Groups tend to be better at generating a large selection of ideas whereas individuals are often better at the problem definition and analysis phases and can often pursue vertical / convergent type of problem solving.

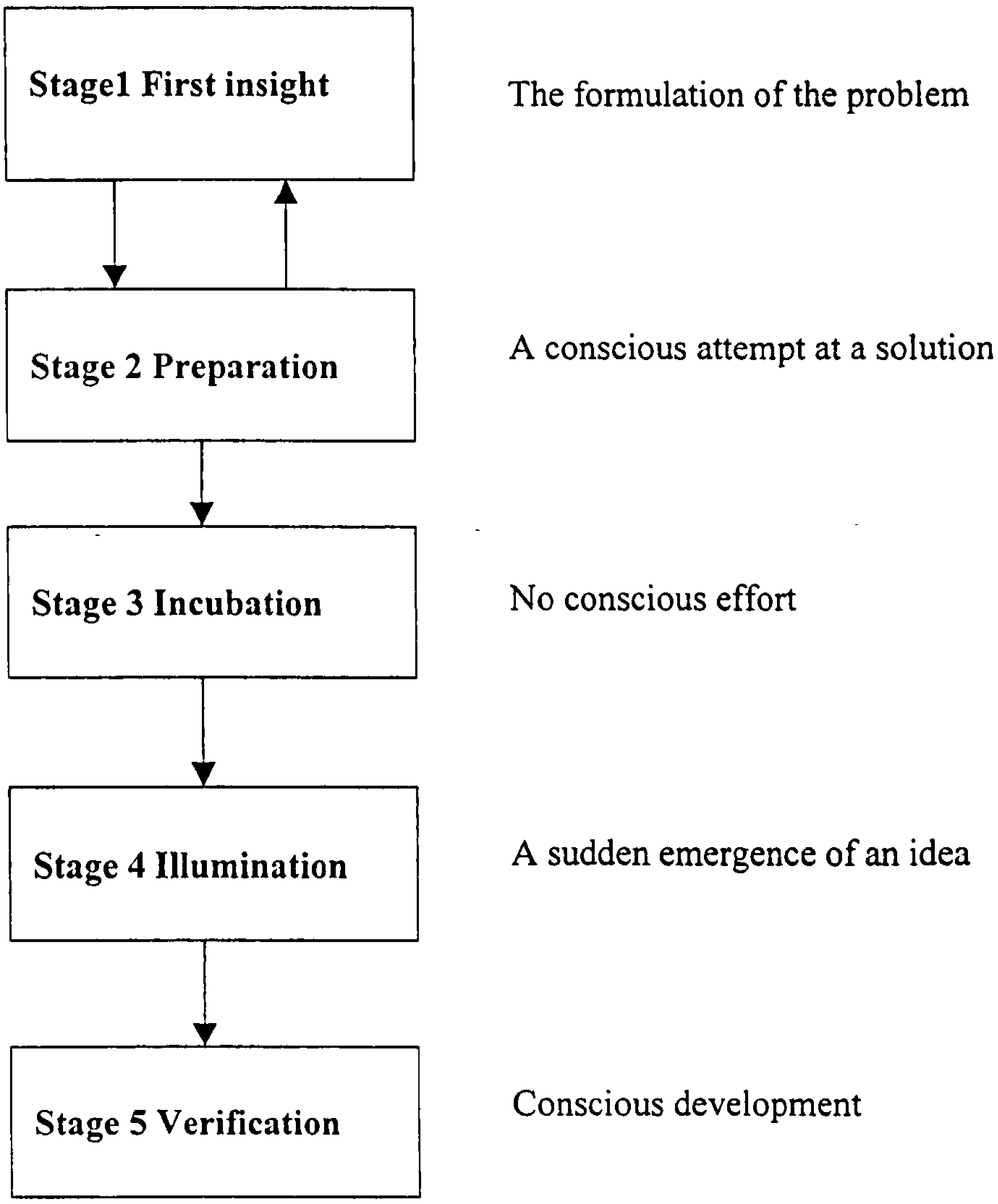

Fig 5.2 Model Of The Creative Thinking Process.

5.2.3 Steps To Enhance Creative Thinking

Creative problem solving is a way of generating new sections in the mind rather than relying on the old ones. One must become more open to both new and different ideas put forward by others.

[6]Cox et al (1991, pp.2-3) identifies six stages in helping to achieve breaking out of this conformed or rutted type of thinking: -

- Stage 1 Define what the problem is. If the definition is too broad it's difficult to make relevant suggestions, if too narrow we limit ourselves. Several definitions of the problem and breaking the problem down into smaller areas can help overcome this.
- Stage 2 Develop some ideas. Initially look at old ideas that have worked in similar situations. Secondly, develop new ideas either by generating new sections of thought or using old sections in new ways. New thinking requires following a different pattern. We are conditioned into valuing logic and reason instead of intuition and creativity. Everyone has creative ideas but these can come at odd times. The author of this thesis would confirm this; he has awoken many times in the middle of the night with ideas to solve some design problem or has been involved in some other activity when ideas or a solution to a problem just appear. The scene of Archimedes jumping out of the bath shouting "Eureka" is probably synonymous to this. Tapping into this under-used resource can develop creative ability.

  Having used the problem solving process to generate a number of possibilities critical judgement can then be exercised.

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[6] COX, Geof., DUFAULT, Chuck., and HOPKINS, Walt. (1991) *50 Activities On Creativity And Problem Solving.* England: Gower Publishing Company Ltd, pp.1-3.

- Stage 3 Solutions. Ideas are analysed and placed into patterns that make sense, which can then be developed into possible solutions, avoiding premature conclusions. An example of jumping to premature conclusions involved a colleague who was at the time working for a large company developing and producing domestic products. In a design meeting discussing their brand new product, a 'Jug' kettle, to his credit he admitted saying "these jug kettles will never catch on", as we know nearly every household in the UK now has one.
- Stage 4 Develop a vision by using the artistic, holistic, imaginative side to the brain. Having decided on a solution or strategy develop its successful implementation. What does it look like? What does it feel like? Etc. Working as a group may involve sharing this vision to achieve the goal rather than resisting the changes that are being proposed.
- Stage 5 Implementation.
- Stage 6 Learning from the process and carrying the lessons learnt forward to the next problem.

Most problem solving situations could apply this process rather than just jumping to conclusions and making incorrect assumptions or just ignoring the problem.

[7]Badger et al (1992, p.42) discusses similar findings to generating new or alternative approaches to creative thinking and lists important factors that should be understood in attempting to enhance creativity within an organisation. "There is a tendency for all of us when confronted with a problem to immediately apply a solution of which we and/or the organisation has had prior experience. This may result in the adoption of an 'inferior response' because we have not examined any alternative approaches".

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[7] BADGER, Beryl and CHASTON, Ian. (1992) *50 Problem Solving Activities*. England: Gower Publishing Company Ltd, p.42.

The list of important factors put forward are: -

- The problem must be approached with an open mind.
- During the phase when ideas are being generated, any attempt to immediately evaluate the viability of a proposed solution will inhibit the creative process.
- To further broaden the range of potential solutions, seek mechanisms to stimulate the submission of apparently illogical or impractical ideas.
- Given that 'two heads are better than one, three heads are better than two, four heads etc., try to involve a number of individuals as in the idea-generation process.

The process of problem solving in product design creates the necessity for making many decisions or choosing between alternatives to enable the development of the product. [8]Dieter (1986, pp.70-71) discusses creative problem solving and invention highlighting a number of positive steps to enhance creative thinking. These steps are introduced to BSc CAPD students in the first year module Product Design and Development along with Brainstorming techniques for generating new product design ideas; both methods prove very popular amongst students. The steps include: -

- Develop a creative attitude. To be creative it is essential to develop confidence that you can provide a creative solution to a problem. Although you may not visualise the complete path through to the final solution at the time you first tackle a problem, you must have self-confidence; you must believe that a solution will develop before you are finished. Confidence comes with success, so start small and build your confidence up with small successes.
- Unlock your imagination. Rekindle the vivid imagination you had as a child. Ask "how", "why" and "what if".

[8] DIETER, George. E. (1986) *Engineering Design, A Materials and Processing Approach.* 1st ed., USA: McGraw-Hill. pp.70-71.

- Be persistent. Contrary to belief that creativity just occurs it often requires hard work. Most problems must be pursued with persistence.
- Develop an open mind. This means being receptive to ideas from any and all sources. We encourage students to carry a small sketchbook to make notes and sketches of interesting design features when they come across them.
- Suspend your judgement. Nothing inhibits the creative process more than critical judgement of an emerging idea. Engineers, by nature, tend toward critical attitudes.
- Set problem boundaries. Establishing the boundaries of the problem is an essential part of problem definition. We always tell our students to play to their strengths.

5.2.4 Brainstorming

Most people when faced with a problem tend to develop a logical solution whereas sometimes a more effective solution requires creative thinking. Brainstorming is well documented by many writers and perhaps the best known and the most used operational technique for creative thinking and idea generation. Developed by Alex Osborne in the late 1930s and introduced in his book in 1953 'Applied Imagination' brainstorming is based on the concept that people are less creative because we prejudge ideas, Osborne focused upon eliminating this pre-judgement of ideas. Brainstorming is normally a group activity typically 4 to 8 people, in which the collective creativity of the group is captured. The objective of brainstorming is to generate the greatest number of alternative ideas on a given topic from the responses of the group in a short period of time. Designed to be enjoyable and freewheeling it is most effective when applied to specific problems rather than general problems and can be used to inject energy into a group's effort. There is clear procedure for the brainstorming session and a set of rules to follow for the participants. This is to aid the creative thinking process, and overcome some of the boundaries to developing new ideas. These boundaries can be overcome and the creative potential of the group released by suspending judgement and criticism. The fundamental principles or rules for brainstorming are as follows: -

- Criticism is not allowed
- Free-wheeling
- Quantity not quality
- Record every idea
- Incubate before evaluating

1. Criticism is not allowed. The idea is to create a supportive environment for free flowing ideas. Any idea is valid, participants must not criticise or pass judgement, suspend judgement until the ideas evaluation phase.
2. Free-wheeling. The participants should divulge all ideas entering their minds without constraint. The other people present should pick up all ideas brought forth.
3. Quantity not quality. A key objective is to provide as many ideas as possible within a relatively short time. 30 to 100 ideas in one half-hour session are possible for a group.
4. Record every idea. Write down every idea however crazy.
5. Incubate before evaluating. The participants should stop and take a break after the ideas generation phase. In some cases overnight.

If members of the group are unfamiliar with the procedure of brainstorming it is a good idea to have a warm-up exercise for approximately ten minutes prior to the main session. The problem for the warm up session should be fairly simple, examples used in the past include generating as many uses as possible for a paperclip or improved design of a tooth brush.

Checklists are a simple method of generating ideas related to the problem or can be used as generalised questions put to the group during brainstorming to help stimulate the flow of ideas.

- Combinations. What new ideas can arise from combining purposes or functions?
- Substitution. What else? Who else? What other place? What other time?
- Modification. What to add? What to subtract? Change the colour? Change the material? Change the shape or alter the motion?
- Elimination. Is it necessary?
- Reverse. What would happen if we turn it backward? Upside down? Inside out? Opposite?
- Adapt. What could we copy? What else is similar to this? Is there a parallel we could use from the past.
- Other use. Is there a new way to use it?

In some cases it is often advantageous to have participants in a session who have different professional backgrounds or experiences i.e. designers, engineers, managers, sales, and marketing personnel.

The following figures 5.3 and 5.4 demonstrate another method of Brainstorming and appears on a design web-site under the heading [9]"CHEAT*SHEETS-Harvey Cards" (1999). As the instructions in the first box indicate, the twenty cards are simply cut out and shuffled, selection is on a random basis then the Brainstorming session can begin. This method relies on a single word as the focus point and sentences that could describe the word are used to help in the generation of ideas. As the word is exhausted another word can then be randomly selected and brainstormed.

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9 *CHEAT*SHEETS-Harvey Cards.* (1999) Core77 Design Web-site. <http://www.core77.com/resource/cards.html>

Harvey Cards	Animate	Contradict
Cut 'em out. Shuffle 'em Up. Start brainstormin'. Let it be random and don't Skip hard ones. Brought to you by: http://www.core77.com	Modilize, bring life to inanimate subjects (having Human qualities). Apply repetition, Progression, narration.	Contradict the subjects original function, reverse and deny! Visualise your subject in connection with the reversal of the laws of nature, gravity, magnetic fields, growth cycles, procedures, rituals.
Symbolise How can your subject be Imbued with symbolic Qualities? What can you do To turn your subject into A symbolic image, a public symbol?	**Superimpose** Overlap, cover, overlay. Super-impose dissimilar images or ideas. Combine sensory perceptions, (sound/colour, etc.) Combine different point of View synchronistically.	**Transfer** Move your subject into a new situation, environment or context. Adapt, relocate, dislocate to a new environment.
Add Extend, expand, supplement, magnify your Reference matter, make it Bigger.	**Substitute** Exchange, switch, and replace. What other ideas, image, etc. can be substituted?	**Distort** Twist the subject out of its true shape or meaning. How can you misshape it? Can you melt it, burn it, make it fatter, wider?

Fig 5.3 Brainstorming - Harvey Cards 1

Transform	Sympathise	Analogise
Convert. See your subject In a state of change. Think of "cocoon to butterfly" transformations.	Relate to your subject. Put Yourself in it's "shoes". Think of it as having human Qualities.	Compare. Draw associations, seek Similarities between things that are different. What logical or illogical associations can I make?
Subtract	**Isolate**	**Disguise**
Simplify, omit, remove Elements. What rule can you break?	Separate, set apart, crop, Detach. Use only parts. What elements can you Detach or focus on?	Camouflage, conceal, deceive, encrypt. How can you hide, mask and shift your subject to another frame of reference?
Change Size	**Repeat**	**Mythologize**
Make subject bigger or Smaller. Change proportion, relative size.	Repeat a colour, form, shape, or idea. Restate, echo, duplicate in some way.	Build a myth around your subject. How can you transform your subject into an iconic object?
Fantasize	**Combine**	**Parody**
Fantasize your subject. Use it to trigger surreal, Preposterous, outlandish, Outrageous bizarre thoughts. Think "what if" thoughts. What if alligators played pool or day and night happened at the same time?	Bring things together. Connect, link, unify, mix Merge, rearrange. Combine ideas, materials, Technologies.	Ridicule, mimic, mock, caricature. Make fun of your subject.. "Roast it", transform it into a visual joke or pun.

Fig 5.4 Brainstorming - Harvey Cards 2

The words used in this case such as 'Add', 'Transform', 'Transfer' and 'Substitute' etc would suggest that the product idea is already selected or in place and this type of brainstorming session would be more suited to generate ideas to further develop or modify the product.

A similar method to the above to generate ideas involves selecting a listing of words at random from a dictionary these can be tabled and used for the Brainstorming session and then changed on a regular basis.

5.2.5 Synectics

Synectics refers to the joining together of different and apparently irrelevant elements. [10]Evans (1991, pp.71- 72) discusses how William Gordon during the 1950s formalised the technique he called synetics following research into some of the notable historic discoveries and found an analogy with a similar problem in nature or elsewhere in life. Group sessions can be held which go through a series of steps beginning with the background information and reducing the problem to its barest, followed by searching for a natural analogy. Synectics differs from brainstorming whereby group members work together collectively for a solution to a set problem rather than generating large numbers of ideas. Examples of this process include the following: -

- Sycamore leaf that spirals to the ground producing the helicopter blade effect.
- Compressing potato crisps into a small place the analogy was found in leaves although fragile they are found compressed and undamaged.

[10] EVANS, James. R. (1991) *Creative Thinking, In the Decision and Management Sciences*, USA: South-Western Publishing Company, pp.71-72.

- Bats in flight emit sound, which bounces off obstacles i.e. they use sonar for detection purposes, this analogy as been used successfully in radar and sonar developments.
- The flaps on aircraft for lift or dive are similar to birds using their wing and tail feathers to obtain the same desired effect.
- Snowshoes developed from the wide feet / paws of animals who can walk on the snow without sinking and divers flippers based on the webbed feet of birds for swimming.
- Many packaging devices for protection are derived from nature's way of protecting seeds.

There are usually four types of analogies used: - direct, fantasy, personal and symbolic.

Direct analogies usually involve finding a parallel situation in real life. Often these have been linked to biological solution to a similar problem. Water jet propulsion, was the 'Jet Ski' developed on the analogy of the squid? Squids suck water in and squirt it out to produce jet propulsion.

Fantasy analogies require viewing a problem as an idealistic wish rather than an actuality or sometimes what may seem impossible wishes. Humans have wanted to fly, swim under water or travel in space and developments in aircraft, micro-lights, helicopters, submarines and the space shuttle have allowed mankind to achieve this. Running a car engine on hydrogen gas where water is the fuel is such a future wish, as is using a washing machine without water to wash clothes where some type of cleaning gas could be utilised instead.

Personal analogies are when you or the team place yourself as the component or design, you take on the role of the product or problem itself. For example how would I behave if I was the car and its driving is fully automated by computer?

Symbolic analogies make use of metaphors relating aspects of one thing with that of another. [11]Cross (1994, p.41) gives examples of the 'friendliness of a computer', the 'head' and 'claw' of a hammer and a 'tree' of objectives.

5.2.6 Morphological Analysis

Morphological Analysis is well documented by many authors and uses a systematic approach to develop a grid system, a simple matrix or a 3 dimensional box to examine combinations of attributes along several dimensions i.e. in the x, y and z plane.

The following example will illustrate how morphological analysis can be applied to product design. The design problem is to develop a torch for use by the emergency services. The first stage is to identify two or three main functions that must be considered for the torch. For this particular product I have chosen: -

1. The source of power to illuminate the torch.
2. The environment the torch will be used in.
3. The main material the torch will be constructed from.

A listing is made of the various possible ways of achieving these key functions then a matrix is constructed whereby each function appears as a major axis and each possible way of achieving the these key functions is a co-ordinate. Figure 5.5 shows a possible design solution for each cell representing the power source to illuminate the torch, the environment the torch will be subjected to, and the various types of materials the torch will be constructed from. This amounts to 2*3*4 = 24 combinations, some of which can be eliminated as being unsuitable or not practical through various reasons.

[11] CROSS, Nigel. (1994) *ENGINEERING DESIGN METHODS, Stratergies for Product Design.* England: John Wiley and Sons Ltd, p.41.

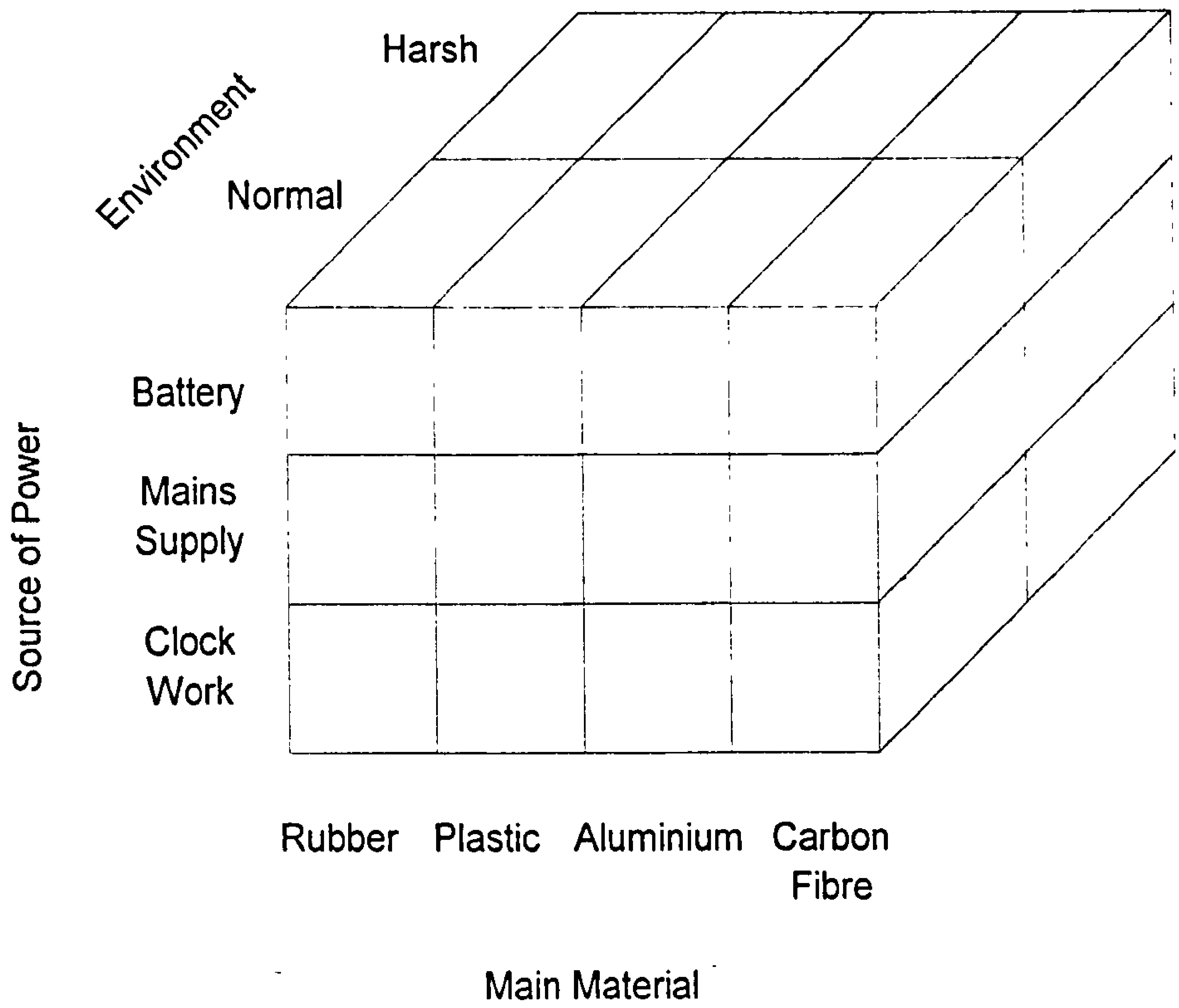

Fig 5.5 Morphological Analysis showing main design functions of an emergency torch

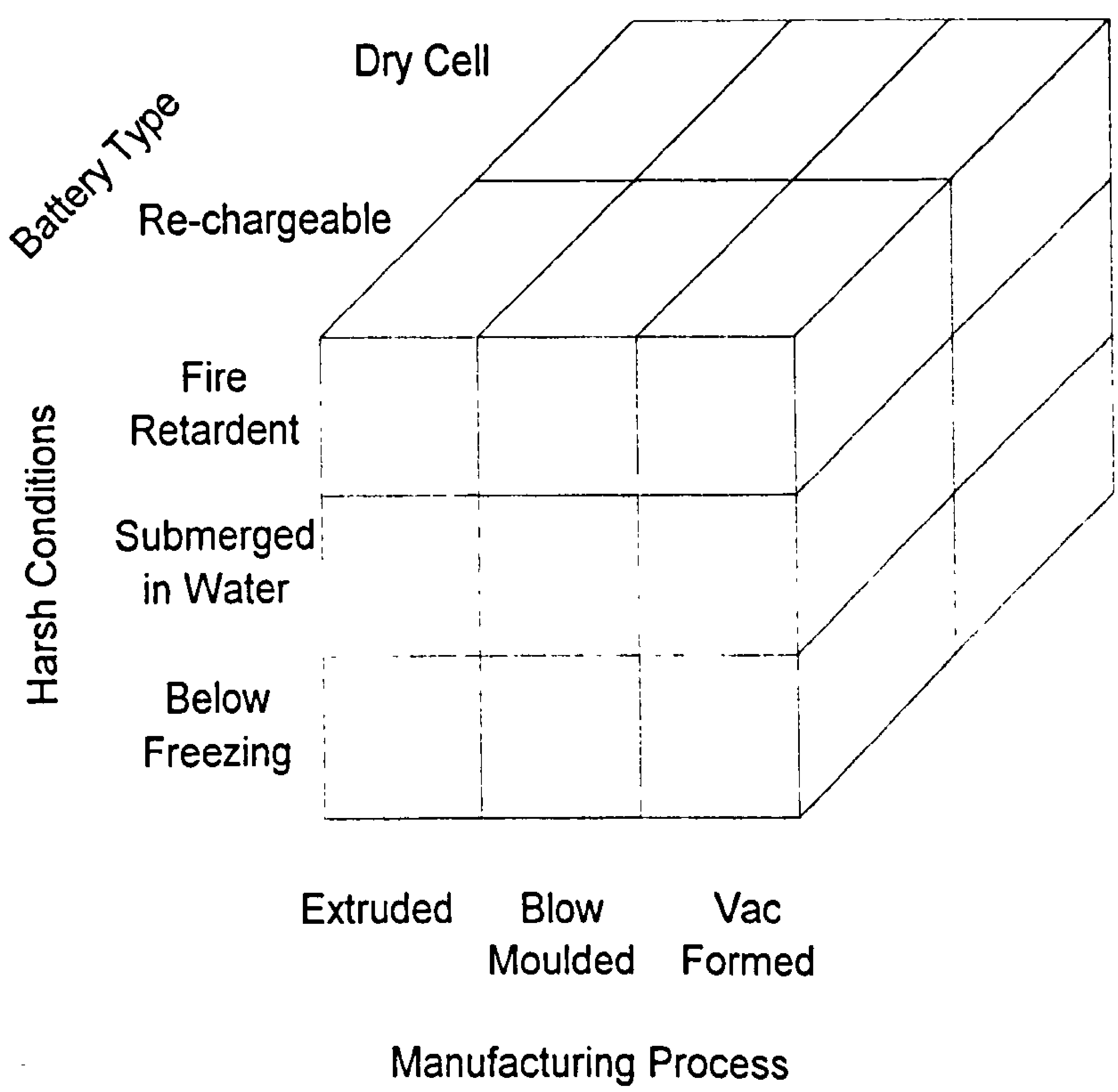

Fig 5.6 Morphological Analysis derived matrix showing the most promising solution of an emergency torch

Figure 5.6 represents the matrix that is derived from the cells that show the most promising solution. In this case battery for the power source, severe / harsh conditions for the environment, and a type of plastic for the main body which accounts for 2*3*3=18 possible combinations, this again can be broken down in more detail. Equally a matrix with the types of plastics suitable for the severe operating environment of fire, submersed in water or freezing conditions could be used to highlight options available. Using this type of analysis provides a formal approach so that innovative problem solutions need not be overlooked.

5.2.7 Invention

Generally invention can be considered to be the result of creative thoughts producing something novel and useful. A large number of inventions have been shown to be classified into several categories:

1. Direct solution to a problem. This involves deliberate design that will satisfy the need.
2. The labour saving concept. An existing process or mechanism is changed in order to save effort or dispense with the human operator. Examples are CNC machine tool or robot automation in the automotive industry for assembly / paint spraying or loading cement bags onto pallets where the dust environment is detrimental to the operators health.
3. The simple or multiple combination. A form of invention that brings together simple combinations of two existing inventions to produce a new result. The modern can opener with integrated bottle opener is an example of this.
4. Serendipity. A chance finding or accidental discovery. The author has had first hand experience of this whilst working in the steel production industry when a production manager got the mixture of 120 tonne of molten steel wrong. It was rumoured the manager was threatened with the sack. Subsequent testing of the steel showed excellent impact properties at low temperatures. The steel was marketed all over the world, where it was used for crash barriers in countries where operating winter temperatures dropped well below freezing.
5. The adaptation of an old principle to an old problem to achieve a new result. The creative step consists in bringing the proper scientific principle to bear on the particular problem, so as to achieve the useful result. Trevor Baylis inventor of the clockwork radio is a good example of this. The inventor's idea was to harness

human energy to provide power; the result, a generator utilising a clockwork technology as the power source.

6. Application of a new principle to an old problem. A problem is rarely solved all the time; its' solution is based on the current limitations of knowledge. As science becomes available its' application to old problems may achieve startling results. Examples include Teflon coatings to produce non-stick saucepans, these developments achieved through the space program, and Mike Burrows who invented the bicycle with a one piece carbon fibre frame further developed by Lotus into the bicycle on which Chris Boardman won his 1992 Olympic gold medal.
7. Application of a new principle to a new use. Applying new principles in completely different disciplinary areas of technology. An example of this is in the use of rapid prototyping techniques applied to medical conditions i.e. a scan of the jaw can be taken and then the 3D data can be passed to a rapid prototyping machine to produce a sterolithography resin model of the jaw. Surgeons can thus make vital decisions or even practice the operation on this prototype before they carry out the actual operation. Another example is applying laser technology in medicine e.g. eye operations and even insertion of a microchip in the eye to facilitate vision.

5.2.8 The Team Approach To Innovation.

The Professional Engineering journal published an article [12]'The innovative imperative' (Sept 1999, p.24) which makes the statement that "the biggest spur to innovation is competition, and the delivery of innovation is more and more dependent on collaboration"

[12] *The innovative imperative; Accelerating product development time and information systems put yet more pressure on firms to innovate.* (Sept 1999) Pullin, J.(Editor). UK: Professional Engineering, Vol 12 No17, MX2000-Manufacturing Excellence, p.24.

Lone inventors like Mike Burrows, Trevor Baylis and James Dyson who have the original design idea often still require a highly skilled team in their own right to develop, manufacture and market the product. Lotus provided this technical backup with their extensive knowledge of moulding composites and wind tunnel testing to improve the aerodynamics of Mike Burrows composite bicycle.

In the case of Trevor Baylis the inventor of the clockwork radio the invention was only the start of along process of innovation transforming the prototype into the aesthetic, technical specification to meet the commercial markets. [13]The British Council's (1999) article on the inventor highlights how he had to collaborate with others in a partnership of technical skills, market research, commercial, finance and intellectual property rights. The project team needed to understand engineering, design and commercial issues to develop the product from the initial idea, the chosen team were skilled in engineering even if they were marketing or design specialist. A materials engineer designed the material for the spring, a radio engineer the radio board, an electrical engineer helped to develop the right generator and a mechanical engineer put it together. In essence they had to work together to produce a radio that was robust for the market place, and energy efficient.

With reference to an article by [14]Howell (1999, p.32) the importance of innovation to companies' success cannot be over-emphasised. Dyson states "We cannot afford not to strive continuously for innovation". Dyson's products provide an example of how to brilliantly exploit innovation in household cleaners, this from one of the fastest growing manufacturing companies in the UK.

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[13] THE BRITISH COUNCIL (1999) *Trevor Baylis – inventor of the clockwork radio; innovation – invention was just the start...* England: <http://www.britcoun.org/science/science/personalities/text/ukperson/baylis2.htm> (accessed 13/12/99)
[14] HOWEL, David. (11th Aug 1999) *INNOVATION; Ideas inaction.* UK: Professional Engineering, Vol 12 No 15, p.32.

Developing improvements in product innovation can be achieved through the early involvement of wide-ranging functions in the product design process. These include techniques of design for manufacture, design for assembly, structured approaches such as quality function deployment, risk assessment, cost planning and control but more important getting multifunction teams involved as early as possible i.e. making use of concurrent / simultaneous engineering concepts. The article reports on a recent survey stating "Companies that pursue a corporate culture which is highly conductive to innovation in the form of opportunities to foster creativity, open discussion groups and decision-making structures are more successful innovators than those who attach little importance to this type of participatory framework".

[15]Pullin's article (1999, pp.14-16) opens by saying British manufacturing industry is disturbingly complacent about the process of innovation and few were managing the process at all well. With as many as 70% of the surveyed companies relying on customers for new product ideas and 50% of companies scanning their competitors for inspiration there was little evidence that company staff, academia or independent researchers were being used to identify opportunities or generate ideas.

The concept of forming multifunctional project teams to drive product innovation is accepted more in theory than in practice and is often allocated to an engineering department rather than a team. Innovation needs to be treated seriously by the management within a company and a structure created to support projects, which are different from day to day manufacturing operations. Innovation is seen as a way of gaining a lot of competitive advantage especially if the company can react quickly to market demands.

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[15] PULLIN, John (1999) *Innovative rethinking*. UK: Professional Engineering, Vol 12 No 18, pp.14-16.

5.3 Applying Design Creativity / Innovation To New Product Development

[16]Pedgley (1996, p.2): - states "innovation in design can come about when the designer's creative talents, both technical and aesthetic-based (though not necessarily combined) are in high demand on a product. When the designer is free to explore changes to both the product and its environment, products increase their likelihood of being innovative".

Figure 5.7 highlights the author's model of the relationship between the various types of designer and design creativity applied to new products. The model identifies the concept designer or inventor initially having the opportunity to apply the most creativity in the way of concepts or ideas into the product design. At this point the knowledge of the new product is at its least. As the product is developed with time the knowledge of the product increases but the creativity curve tails off, i.e. by the time the analysis designer tests the product, applying creativity to the new product is at a minimum.

This would suggest that lateral or divergent type of thinking is most appropriate in the first instance for the concept designer or inventor in applying imagination to generate many ideas and concepts. [17]Hurst's (1999, p.33) statement "the basic thought process employed in generating ideas during the concept stage should be that of lateral thinking" would support this.

Once the design solution or problem becomes more tightly constrained and the product is developed so a more logical approach is necessary and vertical or analytical thinking plays a larger role in the process. [18]De Bono's (1971 p.221) observations also support

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[16] PEDGLEY, Owain. (25th June1996) *Innovation and Creativity in Industrial Design.* <http://www.CORE77.COM/reactor/inno.html> p.2. (accessed 21/10/99)
[17] HURST, Kenneth, S. (1999) *Engineering Design Principles.* London: Arnold, p.8; p.32; p.33.
[18] DE BONO, Edward. (1971) *Lateral Thinking for Management.* England: Pelican Books, p.3; p.221.

Fig 5.7 Applying Design Creativity To New Product Development

this. He sees lateral and vertical thinking as being complementary, stating "Lateral thinking is concerned with choosing concepts, vertical thinking with using them. Lateral thinking requires vertical thinking to select and develop the ideas that are generated. Vertical thinking requires lateral thinking to establish an effective starting point".

The abilities and level of skills in designers can vary, some prefer the open-ended kind of design problem where there are few imposed constraints and the imagination can run wild, while others prefer more tightly constrained problems. It is important for the designer to recognise the nature of the design problem and apply a balance of either imagination divergent thought or logical convergent thought in what they feel is the most appropriate for the situation.

[19]Lawson (1995, p.109) suggests "rarely is one mind responsible for the entirety of a creative product". Where in the innovative process does the creativity lie? Is the concept designer or inventor just creative or should we include all those who refine the design, develop and realise the product. It would suggest that some designers are good at generating novel design ideas while others are better at developing or engineering them.

The BSc CAPD students are exposed to wide-ranging skills that take them across all these design boundaries from concept design to analysis i.e. the students have a menu of skills to choose from. Students can pick from this menu of skills and further develop them to a high level and thus specialise in a particular design field especially once in a design position within a company.

[19] LAWSON, Bryan. (1995) *How Designers Think, The Design Process Demystified* 2nd edition. Oxford UK: Butterworh, p.109.

5.4 Can The Computer Suppress Or Limit Design Creativity?

Computers can provide a creative environment in some situations and suppress design flair or limit design creativity in others.

[20]Greek (1999, p.44) discusses 'Triz': the acronym is Russian for the theory of inventive problem solving, the philosophy is based upon encouraging natural creativity. Contrary to the belief that engineers are imbued with natural creativity, following the study of 'Triz' engineers feel creativity is often suppressed, due to a rigid company hierarchy, which reduces initiative of young engineers. Another influencing factor stated is the "Overdependence on computers and the almost ingrained deification of the power of new technology limits engineers from looking more closely at complex problems".

It would suggest designers / engineers initially need to step away from the computer to look at the problem then redefine the problem in order to obtain a fresh perspective of the situation.

We have seen incredible developments in computer hardware and software that can provide a digital creative environment for design: -

- 3D modelling
- Surface modelling
- Rendering tools
- Model manipulation
- Virtual Reality
- Animation

[20] GREEK, Dinah. (1999) *Beginners guide to genius; Incisive thinking is something you're born with and can't taught? Not according to a theory called Triz.* UK: Professional Engineering, Vol 12 No 7, p.44.

The proof has been the excellent standard of design work BSc CAPD students have produced for assessment, design competitions, and projects etc which has been commented upon very favourably by both external examiners and design competition judges.

When applying colour or rendering techniques to improve the aesthetic appearance of a product the computer can prove advantageous. Students can quickly scan a sketch of a 2D concept of their product and pass this data into a software package such as PhotoShop to render the product with startling results in a matter of minutes.

If we are prescriptive and tell students to design a particular product with a set design brief via assignments, projects or design competitions the students can accomplish this. However, we have found from experience of project interviews that if students are given a completely free hand with an open design brief to design something original, a number of students struggle to generate original ideas especially when working on their own. In this situation students often rely on sitting at a computer to generate concepts rather than thinking through the ideas and producing hand sketches of the product. Computers at this moment in time lack the flexibility and cannot cope with the concept stage of the design process. The design is often then compromised through using computer primitives in generating the model.

Group projects, in particular the final year module Design Enterprise Studies, have helped stimulate design ideas between members i.e. the students feed on one another to achieve a collective product goal and many students comment very favourably on this module.

On some occasions the opposite scenario occurs when students have good concept designs but with very complex geometry or curves and ask "but how do I model it on the computer to produce the 3D CAD image of the product?" It could be argued that the students' knowledge or level of skill in using that software, or the ability of the software itself to generate these complex shapes, is limiting or restricting their ability to produce creative design. The students may then opt for an easier solution of a less creative design that can be modelled easily.

[21]Hursk (1997) observations on creativity in the design process would support this: -

- Early creative ideas are still drawn on scraps of paper
- Computer based design systems do not recognise this stage of the process
- Digital creativity tools support only certain kinds of creativity
- A degree of computer literacy is required
- Information technology is a barrier for many people

In the future Reverse Engineering may play an important role to help alleviate this restriction in creative product design process. In the first instance the complex shaped prototype of the product is sculptured or physically made. Then as digitising / scanning techniques are further developed the model can be digitised or scanned to capture and produce the CAD data that is downloaded to the CAD system to generate the 3D CAD model of the product. This associated data can be used for producing working drawings, details of mould design of the product and so on i.e. reverse engineered.

5.5 Can Creativity Be Taught Or Improved?

Can creativity be taught or improved? [22]Rawlinson (1993, pp.89-90) sees a more appropriate question of "Can the barriers to creative thinking be removed" his reply is a categorical Yes, as long as the barriers to creative thinking can be identified, accepted

[21] HURSK, S. (1997) *Digital Creativity Tools, Creativity in the Design Process*. England: <http://sgi-hursk.lut.ac.uk/~avrrc/Cade97/sld008.htm>
<http://sgi-hursk.lut.ac.uk/~avrrc/Cade97/sld011.htm>

[22] RAWLINSON, Geoffrey J. (1993) *Creative Thinking and Brainstorming*. England: Gower Publishing Company Ltd, pp.89-90.

by the person and removed. The author agrees with these observations but feels creativity cannot actually be taught. Some students are naturally creative, however, exposing all students to creative techniques can help foster a creative attitude. [23] De Bono (1971, p.3.) makes the statement "When creativity is regarded as a magic gift, there is nothing that can be done about it if you are not lucky enough to have the gift. But everyone can develop some skill in lateral thinking and those who develop most skill will be most creative".

Companies are expected to develop successful new generations of products whilst reducing costs and shortening development time, therefore the importance of creativity and innovation in product design and development cannot be over emphasised and is used by many companies to gain a competitive edge over its rivals. However, developing a creative environment and becoming creative requires effort by both staff and students in academia and product designers and managers in industry by thinking in a new way and taking some risk. It has been demonstrated that various activities or techniques such as lateral thinking, brainstorming and group or team work can help in stimulating / improving creativity and provide the vehicle in improving the process of problem solving and generating design ideas / solutions. However, these activities must be enjoyable to undertake the added benefit is those product design teams or individuals who enjoy their work often learn more and are more productive.

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[23] DE BONO, Edward. (1971) *Lateral Thinking for Management*. England: Pelican Books, p.3; p.221.

Chapter 6

6.0 Students Taxonomy Of Design Skills

The following highlights a checklist of designer Attributes, Qualities and Skills required for graduates pursuing jobs in the area of Product design based upon observations from the company survey and the BSc Computer Aided Design curriculum.

6.1 Designers Checklist Of Skills

1. Educational Background For The Position.

Which design discipline does the company prefer? Product, Industrial, Engineering, Electrical, Electronic, Mechanical, Manufacturing, Automotive etc - tailor your final year project if necessary towards your chosen design discipline.

Becoming a Graduate member of a Professional body may help in securing the position e.g. Institute of Engineering Designers (IED).

Produce an excellent portfolio over all years at University, demonstrating all aspects of the design process. Show creativity/innovation in design and highlight your specific skills.

2. Work Experience, Practical Skills.

Work experience and practical skills are an essential requirement for most companies, sandwich placement is ideal. Failing this gain as much practical experience as possible from the course through design/make projects, company projects, visits and national design competitions.

Maintain a continuing professional development once in the company to update your skills, often a job is not for life these days.

Consider the skill proficiency you feel you have achieved under the following headings. This will assist you in highlighting your strengths and weaknesses. You may categorise the skill levels as **None, Basic, Competent, Good, or Very Good.** Play to your strengths and improve on your weaknesses.

3. Communication, Manual Drawing Skills

Produce good freehand drawings, concept design sketches and aesthetics. These are essential skills.

Read and interpret engineering drawings.

Think in 3D.

Rendering skills using marker pens, being superseded by computer.

Produce a physical prototype model of a product in foam, wood etc.

Report writing.

Oral presentation.

4. Use Of Computers In Design

Research product data and Standards using CD and Internet search engines.

Word-processing reports, spreadsheet, database and scanning techniques.

Visual Presentations using PowerPoint.

Operate a CAD system for 2D drawing using AutoCad, PowerCAD etc often guaranteed jobs for graduates.

CAD training on a major system for 3D modelling using either Pro/Eng, CATIA, CADD5X, I-DEAS, ALIAS, Solidworks, Studio Max, Vellum etc often guaranteed jobs for graduates.

Produce part drawings.

Produce detail drawings.

Produce assembly drawings.

Operate a CAD system for surface modelling using DUCT, RHINO etc

5. Analysis Of Design

Produce calculations for mass, volume, bending moments and 2nd moment of area etc.

Carry out basic stress analysis calculations on a component or product.

Carry out Finite Element Analysis on a small component.

Utilise ergonomics and anthropometric data in the design process.

6. Business

Be able to plan a job.

Work to target dates and budgets.

Work as a member in a Design Team and operate in a multi-functional environment fully integrated into manufacture/production (Concurrent engineering).

Deal with clients effectively.

Marketing.

Costing.

Appreciation of the role of other departments.

7. Manufacturing Methods

Knowledge of manufacturing processes: - casting, forging, presswork, welding etc.

Knowledge of material properties for steels and other metals.

Knowledge of material properties of plastics.

Computer Aided Manufacture (CAM)

An understanding of Electrical / Electronic systems.

Design for manufacture.

Design for assembly.

Design for recycling and Packaging.

Knowledge of Stereolithography and Rapid Prototyping techniques.

Have an appreciation of modern techniques of Just in Time, Kanban, FMEA etc.

During a design competition presentation (October 1999) to final year BSc CAPD students a leading practising design consultant made the following statement: -

"A student can succeed in this profession by having three attributes;

- Being organised.
- Being articulate.
- Being an average designer".

The author's response to this is, "Yes, be organised and yes, be articulate but students must strive to become more than an average designer".

6.2 Skills Model For The Concept, Industrial, Product, Engineering, And Analysis Designer

Fig 6.1 shows the Author's model for the distribution and range of skills for different types of designer. There is a broad band of skills across the entire range for the different designers with a narrow band of skills that could be associated with a specific type of designer.

Dealing with the Concept Designer first (on the left-hand side of Fig 6.1) it may be argued that their main skills could be biased to being creative, generating as many ideas as possible and proposing these solutions through sketching techniques. Likewise, if we take the Analysis Designer at the other end of the spectrum, their main skill may be biased to mathematical theory for stress calculations, finite element analysis or fluid flow analysis i.e. predicting how the product will behave in its intended environment.

The Industrial Designer is often associated with the aesthetics and artistic rendering, applying ergonomics / anthropometrics to the product and producing sketch models in

Fig 6.1 Skills Distribution for Different Types of Designer

foam, wood etc. where as the Engineering designer is linked to the technological aspects of the product i.e. detail design, rapid prototyping, mould design, tooling and materials. It must be recognised that these designers achieve a high level of skill in their particular area and that most have an appreciation of the other designer's skills and often migrate across these boundaries when developing products.

The BSc CAPD course was designed to produce a new type of designer who could combine the skills and theoretical knowledge of an engineer and the conceptual ideas of the industrial designer. A designer, who could work at both ends of the design spectrum, able to produce design concepts but also having the technical knowledge to communicate and liaise effectively with manufacturing, materials and production engineers to achieve the product goal. The BSc CAPD graduate would have a broad range of transferable skills to enter a new and fast changing job market that did not offer a traditional career for life, but required adaptability. We needed to offer a richer blend of skills between Industrial Design, as then offered in the Three Dimensional Design Subject area of the School of Art and Design (SAD) at Wolverhampton, and traditional Engineering Design offered in the School of Engineering and the Built Environment (SEBE).

One of the first close collaborative ventures between schools within the institution the course has bought together design, engineering, manufacturing and computer skills. Integration has been the key word, the two schools offering the broad range of inter-related skills of: -

- Design Awareness and Visual Communication
- Engineering Design
- Manufacturing and Technology
- Computing and Information Technology

- Business

The other integrating vehicle for these skills has been the practical design projects that occur in each level (year) of the course.

It would therefore seem appropriate to place the majority of students who graduate from the BSc CAPD course in the middle of Fig 6.1 distribution curve and it is felt that the majority of jobs lie in this area. These students have currency, because of the wide range of skills they have to offer industry, in particular the use of computers in design.

Chapter 7

Summary Of Conclusions

In achieving the aims and objectives of the BSc CAPD course, as set out in Chapter 2 (2.3.2.1 Aims), (2.3.2.2 Course Objectives), and meeting industry's needs for designers (designer's skills) the following listing is a summary in terms of what is perceived to have been successful in providing an effective learning environment for product design in higher education through an integrated approach: -

- The integration of engineering and art and design staff to deliver the curriculum.
- The project base of the course, especially group projects and live projects (industrial) that provide the vehicle for an integrated approach to curriculum development, teaching, learning, creativity and innovation in Product Design.
- Integration of computers into the design curriculum to develop technical and design skills.
- Technology supported learning in product design. The use of Video Conferencing in a distance learning environment and the development of a Computer Assisted Learning (CAL) package / tutor system for teaching 2D CAD.

The B.Sc. Computer Aided Product Design (CAPD) course was modified in October 1996. The aim was to allow students more flexibility and the opportunity to select and specialise in a vocational area for future employment. Students could choose from six specialist option routes in years 1 and 2 of the course with a common final year (Ref. Appendix 5 options). Over the two years that this was in existence approximately 98% of the students selected either Computer Aided Design (CAD) or the Industrial Design route, with low numbers, 1% or 2%, opting for Business Studies or Languages. Initially one or two students had elected to study Consumer Electronics; however, such small numbers were not viable when taking into account staffing and resources requirements.

The lack of interest in the new options suggests that the students felt the BSc CAPD course was already broad in nature and suited their requirements. This finding is further backed up by analysis of the company questionnaire which, taking into account the variety and range of differing product companies, indicates that the existing BSc CAPD curriculum is broad based enough to cover and meet the majority of companies needs when recruiting product designers. Obviously the level of skill requirement is very much dependent upon the particular company and their product range. Implementing a complete new curriculum is therefore not a requirement. However, it is important that the curriculum is modified and up dated on a continuous basis, based upon feedback from students and industry and on the developments in new technologies such as Virtual Reality software, Holographic design, model prototyping techniques and new media techniques for presentation and marketing the product.

The field of product design is rapidly changing due to the increasing use of computer based technologies. Design for manufacture, design for assembly / disassembly and design for recyclability have resulted in the development of new approaches to design, the new approaches to include feature modelling, concurrent / simultaneous / parallel engineering concepts. The adoption of new methodologies to meet these new concepts indicates industrial requirements that Designers coming from an engineering background have broad perspectives and greater interactive viewpoints.

The possible reduction in the number of design students obtaining practical experience during the course through work placements and its associated problems requires Universities to strive to include as much practical experience in the curriculum as possible. Liaising with companies for 'live' projects and National design competitions can play a vital role in achieving a more practical solution. Co-designing i.e. students working together on group projects, in particular 'Live' projects, can provide a good foundation in developing the integrated philosophy of concurrent and parallel engineering concepts. Students acquire skills in concept design, analysis, manufacturing, prototyping, marketing etc and thus take on these roles whilst at University. This gives students more flexibility for employment and equips them with some of the necessary skills to be able to communicate with the specialised personnel involved in a company's design team.

The integrated philosophy approach to product design is introduced to First year BSc CAPD students through concurrent / parallel engineering concepts, stressing the important relationship between the design team and other key personnel, such as, manufacturing and marketing departments. The curriculum has been designed to enable students to work in groups on a number of design projects throughout the course to help foster the team-working approach. In particular, modules such as Graphical Modelling and Design Practice in the second year and Design Enterprise Project in the final year were designed to encourage this. Industrial based assignments and projects have played an increasing role in achieving this.

Computers will play an even greater role in the future for higher education product design. The research has shown the development of Computer Aided Learning for an effective learning environment in Higher Education for product design can prove successful.

It has been demonstrated in chapter 3.3 that Video conferencing can play a vital role as a communication tool for a variety of purposes. Video conferencing offers relative low-cost instant visual contact between separated parties across buildings or countries.

Generally, both staff and students could see the potential of using videoconferencing as a supplementary teaching aid in a distance learning environment.

With careful planning and preparation, utilising the video conferencing system, telephone, fax, and Email, it would be possible to deliver the same MSc programme as discussed in chapter 3.3 or other similar programmes with reduced tutoring and travel cost. A programme may consist of one week of lectures based in the other country accompanied by a second week of tutorials at Wolverhampton University via link with the second party.

The results of the evaluation in chapter 3.2.2 have shown that 'DesignView' benefited all students, in particular students with design flair but lacking good technical drawing board skills or design analysis. Overall, the software gave a good insight into the role of Parametrics, and the integration between design and analysis. The author would argue that 'DesignView' operating as described in chapter 3.2 was indeed emulating a CAL/CBL environment. However, integrating a commercial CAD software with CAL under a windows-type system with multi-processing would form the basis for the next development phase, and the proposal for the Engineering Broadnet project for Learning and Teaching 2D CAD (chapter 3.5) came about.

A combination of five factors proposed by [1]Whitlock (1st Feb 2000) is listed in chapter 3.7 for the increasing attention that online learning is receiving: -

i) increasingly rapid change in technology

ii) changing curricula and staff restrictions in FE/HE

iii) the demand for multi-skilling in industry

iv) the national drives for greater inclusivity and lifelong learning

v) the constant search for economies to cope with greater number of students

[1] WHITLOCK, Quentin. (1 February 2000) *TUTOR SUPPORT IN ON-LINE LEARNING*, A report to the Department for Education and Employment and the University for Industry on a literature search, conducted by 'Technologies for Training' UK. pp.2-3.

As previously discussed in chapter (3.5.1) the proposal for developing the 2D CAD training package came about because of the large number of students attracted to CAD related modules and the number of lecturing staff involved. Therefore, it seems appropriate that the reasons for its development fit firmly within categories (ii) and (v) above and in a way category (iv), in that one of the aims of the package was to encourage independent learning by the user. However, it was found that tutor support is still vital when students used the on-line CAD package, as students soon become frustrated if stuck and need encouragement or confirmation they are meeting the assessment criteria. It has been shown that other authors would support this and it is nonsense to believe that tutors will be superfluous once course materials are available on the Internet. [2]Duggleby and Fletcher's article points out "People want the guidance of a tutor. They want access to someone, an expert, who has the experience and knowledge to guide their learning, to motivate them, to congratulate them on their success, and to point out their errors".

Fifty per cent of students who took part in the CAD evaluation questionnaire would further support this, under sub-heading (3.6.2.3 CAD Skills), a further forty per cent remaining neutral to the question. The findings suggest that CAL packages require tutor support and need to work in conjunction with traditional and other teaching methods, not replace them in their entirety.

With reference to item (v) above, 'the constant search for economies to cope with greater number of students', there appears to be little true costing made available in the development and delivery of CAL packages. This could form a good basis for further research. As previously mentioned in chapter 3.6.3 well over 1000 man hours went into

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[2] DUGGLEBY, Julia and FLETCHER, Tony. (July 2000) *Teaching online – fear not* 'The Lecturer' journal, Higher Education Section. Editor Paul Mackay. London: Landmark Publishing Services, p.18.

the 2D CAD learning and teaching package to make it a success, much of this in the Lecturer's own time. If costing were carried out on just a Lecturer's hourly rate alone this would equate to a full time Lecturer's salary for one year. It could be argued, however, that once the package is set up the cost of running it is minimal.

CAL packages dealing with areas such as Mathematics and Languages may be more cost effective than some Product Design areas, in that content does not change to a great extent i.e. Mathematics principles and Languages remain the same. In the case of Engineering, however, new developments, especially CAD and Product Design and Development, move at a rapid rate and this needs to be taken into account when developing the material as it can quickly become obsolete.

Many CAD vendors today recognise the need for some form of on-line training in their software and are building CAD tutorials within their software's 'Help' facility, along with hyperlinks to their Web site and even on-line manuals.

Three models are used in chapter 3.7, described in [3]Whilock's report (1st Feb 2000 p.3) for on-line learning or Web-based training. The three models were proposed by [4]Fryer (1997). The term E-Learning is used to cover all of the three following categories: -

- The Desktop tutor, in effect computer based training (CBT) on the Web, often associated with job training and favoured by the corporate sector because the package is self contained with feedback exercises and needs little pedagogical support. However, it is now being widely accepted that having a tutor on duty or at hand gives added value and is important to its success.

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[3] WHITLOCK, Quentin. (1 February 2000) *TUTOR SUPPORT IN ON-LINE LEARNING*, A report to the Department for Education and Employment and the University for Industry on a literature search, conducted by 'Technologies for Training' UK. pp.2-3.

[4] FRYER, Bronwyn. (September 1997) *Are you caught on the web?* Inside Technical Training. USA. pp. 10-15.

- The "Online Class", through a planned series of activities tutors and students participate in online chats and other interactions by Email and Computer Mediated Communication. Often the learners are geographically widespread.
- The "Ultra Interactive Model" which incorporates video technology, real-time audio and videoconferencing with an instructor

Chapter 3.0 of the thesis demonstrates the successful use and evaluation of all three forms of E-Learning in one form or another, which have taken place during the author's research in the area of Product Design. The learning and teaching package for 2D CAD fits within the first model and the use of Email, Fax, Videoconferencing, and making use of shareware software for the MSc course in Finland falls into the second and third models. It would seem feasible that the three models could be combined as technology advances and becomes even cheaper. The learner accesses the on-line CAD learning package from a remote site or home via the Internet or local area network and has tutor support on-line, via either Email or one to one Videoconferencing.

The following gives a summary of advantages / disadvantages of CAL / Tutoring systems based upon these findings: -

Advantages of CAL /Tutoring System

- Open access, available at any time, geographical distance and location become irrelevant.
- Student centred.
- Caters for different learning curves of students.
- Can be cost efficient once set up.
- Built in assessment.

- Can engage students in the sort of dynamic and interactive learning process favoured by most cognitive models of learning.
- Can present dynamic process i.e. objects viewed and rotated.

Disadvantages of CAL /Tutoring System

- Hardware can become obsolete very quickly.
- Software can become obsolete very quickly.
- Time factor in writing CAL software.
- Time factor in setting up system, testing etc.
- High initial cost incurred, consider capital and hidden costs such as maintenance and system management.
- Reliability, software if poor may break down, crashing due to poor programming and poor testing.
- Suitability. Is the software suitable for the task?

Computer Aided learning or Computer Based learning will assist in developing product design skills, in particular CAD related skills; the internet and video conferencing providing the necessary communication vehicle for delivering the curriculum to students who wish to study in a distance learning environment via resource based flexible learning.

The BSc CAPD curriculum has been developed to educate undergraduates with broad based knowledge of design together with an understanding of manufacturing processes, materials, engineering science, and business. These disciplines are integrated through the use of modern aids in design computing and thus allow the students to develop and experience professional design practice within a high technology environment.

External Examiners and Accreditation panels often comment favourably on the students' degree of imagination, programmes of study, standard of project work achieved and the displays that they put on.

The success of the BSc CAPD course is demonstrated by the employability of its graduates. First destination statistics are very encouraging and indicate that a large percentage of our graduates have gained employment in a wide variety of companies by the time they return to the graduation ceremony in September/October of the year of completion.

The utilisation of a CAD system for 2D and 3D modelling has always formed a significant part of the learning experience in many of the modules for students studying the BSc CAPD course, from an introductory level at year 1 up to a competent level by year 2 and fairly advanced level by the end of the final year. Companies obviously see this as an important skill requirement and the benefits are the number of graduates who have obtained employment in this particular field and command good salaries.

Very few of the prospective students see themselves as studying on an engineering course, so one of the encouraging features of the award has been the number of graduates who have become employed as a product designer in the engineering field.

This success is largely due to the integrated approach throughout the course and the role projects play within the course structure.

Suggestions For Further Work And Product Design In The 21st Century

An original statement made was that the BSc CAPD graduate would have a broad range of transferable skills to enter a new and fast changing job market that did not offer a traditional career for life, but required adaptability. In the future this will become even more applicable with the digital revolution moving at an ever-increasing rate.

There will need to be a modified curriculum to support education for Product Designers/Engineers in the 21st century providing computing digital skills and digital product modelling. How soon will we be rapid prototyping components rather than just prototypes?

The methods by which people learn is also changing with Internet access to vast amounts of on-line learning material, remote learning from the home and work based learning likely to play a bigger role in the future.

Broadband cable, the Internet and wireless links in this digital age are likely to connect companies, employees and consumers alike. It has been shown that with computer links and videoconferencing, staff could become remote workers, computer aided product design could become a cottage industry, working from home with only an occasional group design meeting at the institution and collaborative design-taking place over the network. The same principle could apply to Lecturers in education unfortunately the working week will no longer be Monday to Friday as we move into an ever-increasing 24-hour society.

As today's product lifecycle gets even shorter there is an ever-increasing challenge on the product designer. The network then becomes a valuable tool linking marketing departments with design and suppliers of parts, the manufacturer selling directly to the consumer cutting out the middleman.

Other issues in the 21st century are designing for an ageing society, many may have more money for leisure, and it is here that a new market for product introduction may take place. In a society of throw-away products the other big issue is likely to be in product recycling, and recycling in general, with legislation being introduced and landfills becoming full.

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Appendix I

List of Product Design Courses in England, Northen Ireland, Scotland and Wales, 1993/1994

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Centre of Learning Telephone No	Course Description	Approx No of 1st year places
Anglia Polytechnic University 0223 6327	BSc (Hons) Product Design with Business Management	NA
Barnsley College 0266 730191	HND Design (Industrial)	20
Berkshire College of Art and Design 0628 24302	HND Design (Product Design)	30
Blackburn College 0254 55144	HND Design (Product Design)	NA
Bournemouth University 0202 314144	BA (Hons) Product Design	60-90
Bournemouth and Poole College of Art and Design 0202 537729	HND Design (Industrial Design)	34
Brunel The University of West London 0784 431341	BSc Industrial Design / Design Engineering / Product Design	90-100
Cardiff Institute of Higher Education 0222 551111	BA (Hons) Three Dimensional Design:- Industrial Design	24
Carmarthenshire College of Technology and Art 0554 759165	HND Industrial Design/Engineering	20
University of Central England in Birmingham 021 3315800/1/2	BA (Hons) Industrial Design BSc (Hons) Engineering Product Design	17 24
University of Central Lancashire 0772 201201	BA (Hons) Industrial Design	10
Central Saint Martins College of Art and Design London 071 753 9090	BA (Hons) Product Design	51
Colchester Institute School of Art and Design Essex 0206 761660	HND Design (Industrial Design)	30
Coventry University 0203 631313	BA (Hons) Consumer Product Design	15-20

De Montfort University Leicester 0533 551551	BA (Hons) Three Dimensional Design Industrial Design (Engineering)	12
University of Derby 0332 622222	BA / BSc (Hons) Product Design, Innovation and Marketing. Product Design and Manufacturing	NA
University of East London Essex 081 590 7722	BA (Hons) Product Design	NA
Glasgow School of Art and Design 041 332 9797	BA (Hons) Design (Product Design)	NA
University of Hertfordshire 0727 45544	HND Design (Industrial Design)	12
Hounslow Borough College Middlesex 081 568 0244	HND Industrial Design	NA
The University of Huddersfield 0484 422288	BSc (Hons) Product Design HND Design (Product Design)	25 25
Jacob Kramer College, Leeds 0532 433848	HND Design (Product Design)	NA
Kingston University, Surrey 081 547 2000 ext 2081	BA (Hons) Product Design	30
Leeds Metropolitan University 0532 832600 ex 3022	BA (Hons) Three Dimensional Design Product Design	20
Loughborough University of Technology 0509 263171	BA (Hons) Industrial Design and Technology. B Eng Product Design and Manufacture	NA
Manchester Metropolitan University 061 247 1705	BA (Hons) Three Dimensional Design Industrial Design	25
Middlesex University Hertfordshire 081 362 5000	BA (Hons) Three Dimensional Design Product Design	20
Napier University Edinburgh 031 444 2266	BSc (Hons) Industrial Design (Technology)	NA
University of Northumbria at Newcastle 091 232 6002	BA (Hons) Design for Industry	33
Nottingham Trent University 0602 418418	BA (Hons) Three Dimensional Design Furniture & Product Design	10
Ravensbourne College of Design Kent 081 468 7071	BA (Hons) Three Dimensional Design Product Design	24
University College Salford 061 884 6633	BSc (Hons) Product Design and Development	30

Sheffield Hallam University 0742 532022	BA (Hons) Three Dimensional Design Main Studies - Product Design	28
Southampton Institute of Higher Education 0703 229381	BA (Hons) Product Design and Marketing	NA
South Bank University 071 928 8989	BSc Consumer Product Management Engineering Product Design	NA
Staffordshire University 0782 744531	BA (Hons) Design	25
Suffolk College 04373 255885	BSc (Hons) Product Design and Manufacture. Product Design and IT	NA
Swansea Institute of Higher Education 0792 203482	BSc Product Design	NA
University of Teesside 0642 342363	BA (Hons) Industrial Design BA (Hons) Product Design Marketing	40 35
University of Ulster 0265 44141	BA (Hons) Design (Product options) HND Design (Products and Graphics) at Magee College, Londonderry.	NA
University of Westminster Harrow 071 911 5000	BA (Hons) Product Design (Engineering)	30
University of Wolverhampton 0902 322287	BSc (Hons) Computer Aided Product Design BA (Hons) Industrial Product Design	40 20

	Course Level	Course Code	Course Length	Campus Codes
University of Abertay Dundee				
Food Product Design	BSc	D410	4FT	
Anglia Polytechnic University				
Information Systems and Product Design	BSc	GH57	3FT	
Also available at this site: Chelmsford				
Electronic Product Design	BSc	H680	3FT	
Also available at this site: Chelmsford				
Product Design (HND Top-up)	BEng	H770	2FT	
Also available at this site: Chelmsford				
Multimedia and Product Design	BSc	HH76	3FT	
Also available at this site: Chelmsford				
Law and Product Design	Mod	HM73	3FT	
Also available at this site: Chelmsford				
Computer Aided Product Design	HND	27WH	2FT	
Also available at this site: Chelmsford				
Computer Aided Product Design	BSc	HW72	3FT	
Also available at this site: Chelmsford				
Business Administration and Product Design	Mod	NHC7	3FT	
Also available at this site: Chelmsford				
Aston University				
Biology/Engineering Product Design	BSc	CH17	3FT	
Chemical Product Technology	MChem	F160	4FT	
Engineering Product Des/Geographical Info Systs	BSc	FH87	3FT	
Engineering Product Design/Environ Sci & Tech	BSc	FH97	3FT	
Engineering Prod Des/Geog Info Systs (Year Zero)	BSc	FHVT	4FT	
Engineering Product Design/Mathematics	BSc	GH17	3FT	
Engineering Product Design/Mathematics (Yr Zero)	BSc	GHCT	4FT	
Engineering Product Design (BSc)	BSc	H770	3FT	
Engineering Product Design	BSc	H771	4FT	
Biology/Engineering Product Design (Year Zero)	BSc	HC7C	4FT	
Engineering Prod Des/Env Sci & Tech (Year Zero)	BSc	HF7X	4FT	
Engineering Product Design/Telecommunications	BSc	HH76	3FT	
Engineering Product Design/Health & Safety Mgt	BSc	HJ79	3FT	
Eng Product Des/Health & Safety Mgt (Year Zero)	BSc	HJ7Y	4FT	
Engineering Product Design/Human Psyc(Year Zero)	BSc	HLRR	4FT	
Engineering Product Design/Public Policy & Mgt	BSc	HM71	3FT	
Eng Product Des/Public Policy & Mgt (Year Zero)	BSc	HM7D	4FT	
Business Administration/Engineering Prod Design	BSc	HN71	3FT	
Business Admin/Eng Product Design (Year Zero)	BSc	HN7C	4FT	
Engineering Product Design/French	BSc	HR71	3FT	
Engineering Product Design/European Studies	BSc	HT72	3FT	
Engineering Product Des/European St (Year Zero)	BSc	HT7F	4FT	
Engineering Product Design/Human Psychology	BSc	LH77	3FT	
Engineering Product Design/Politics	BSc	MH1T	3FT	
Engineering Product Design/Politics (Year Zero)	BSc	MHC7	4FT	
University of Wales, Bangor				
Forestry and Forest Products	BSc	D322	3FT	
Forestry and Forest Products	BSc	D323	4SW	
Barking College				
Product Design (Extended)	BSc	E778	1FT	
Product Design	HND	877E	2FT	
Product Design (Extended)	BSc	H778	1FT	
Product Design	HND	877H	2FT	
Bolton Institute of He				
Product Design and Sport and Exercise Science	Mod	BH67	3FT	
Leisure Computing Technology and Product Design	Mod	GH7T	3FT	
Automotive Product Design	BSc	H160	3FT	
Automotive Product Design (4yrs)	BSc	H161	4FT	
Consumer Product Design	BSc	H770	3FT	
Consumer Product Design (4.5 yrs)	BSc	H771	4FT	

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Product Design and Safety & Occupational Health	Mod	HBT9	3FT
Motor Vehicle Studies and Product Design	Mod	HHJT	3FT
Computer Aided Product Design	BSc	HW72	3FT
Computer Aided Product Design	BSc	HW7F	4FT
Enterprise Development and Product Design	Mod	NHD7	3FT
Visual Arts and Product Design	Mod	WH17	3FT
Bournemouth University			
Product Design	BA	E230	4SW
Product Design Visualisation	BA	E231	4SW
Computer Aided Design (Products)	HND	161H	2FT
Product Design	BSc	H770	4SW
Product Design Visualisation	BSc	H771	4SW
Product Innovation and Development	BSc	H772	4SW
Product Design Extended	BSc	H778	5FT
Product Innovation and Development (Extended)	BSc	H779	5FT
Product Design	BA	W230	4SW
Product Design Visualisation	BA	W231	4SW
The University of Bradford			
Health and Personal Products	BSc	B9B2	3FT
Health and Personal Products	BSc	B9BF	4SW
Petroleum Products Engineering	BEng	HJ81	3FT
Petroleum Products Engineering	BEng	HJ8C	4SW
Petroleum Products Engineering (MEng)	MEng	HJV1	4FT
Petroleum Products Engineering (MEng)	MEng	HJVC	5SW
University of Brighton			
Product Design (4 year sandwich)	BSc	E231	4SW
Product Design (4 year sandwich)	BEng	W231	4SW
Brunel Univ			
Product Design (4 Yrs Thin SW)	BSc	H772	4SW
Product Design (4 Yrs Thick SW)	BSc	H776	4SW
Buckinghamshire Chilterns University College			
Forest Products Technology with Forestry	BSc	D316	3FT
Product Design (Conversion to degree)	BSc	H772	1FT
Product Design with Marketing	BSc	H7N5	3FT
Product Design with Management	BSc	H7ND	3FT
Product Design with Multimedia	BSc	H7P4	3FT
Product Design	BSc	H7W2	3FT
Forest Products Technology	BSc	J501	3FT
Forest Products Tech with Environmental Mgt	BA	J5F9	3FT
Forest Products Technology with Management	BSc	J5N1	3FT
Forest Products Technology with Marketing	BSc	J5N5	3FT
University of Wales Institute, Cardiff			
Product Design and Manufacture	BSc	EW12	3FT
Product Design and Manufacture	HND	007H	2FT
Product Design and Manufacture	BSc	HW12	3FT
Univ of Ctrl Eng in Birmingham			
Engineering Product Design	BSc	H770	3FT
Engineering Product Design Foundation Year	BSc	H778	4FT
Univ of Central Lancashire			
Product Design	BSc	H771	3FT
Cordwainers College			
Design, Marketing & Prod Dev (Footwear & Access)	BA	EW42	3FT
Design, Marketing & Prod Dev (Footwear & Access)	BA	JW42	3FT
Coventry University			
Consumer Product Design (MDes)	MDes	E230	3FT
Industrial Product Design	BSc	H771	4FT
Industrial Product Design (Foundation)	BEng	H778	4FT
Consumer Product Design (MDes)	MDes	W230	3FT

De Montfort University			
Product Design	BA	E231	3FT
History of Art & Design and Photo & Video Prod	BA	EV54	3FT
Fashion Studies and Photography & Video Product	BA	EW25	3FT
Graphic Design and Photography & Video Product	BA	EW2M	3FT
Illustration and Photography and Video Product	BA	EW2N	3FT
Product Design	BA	W231	3FT
History of Art & Design and Photo & Video Prod	BA	WV54	3FT
Fashion Studies and Photography & Video Product	BA	WW25	3FT
Graphic Design and Photography & Video Product	BA	WW2M	3FT
Illustration and Photography and Video Product	BA	WW2N	3FT
University of Derby			
Creative Product Design and Marketing	BA	EN75	3FT
Virtual Product Design Technology	BSc	GH77	3FT
Product Design Innovation & Marketing	BSc	H770	3FT
Product Design	HND	077H	2FT
Product Design Engineering	BEng	H771	3FT
Creative Product Design and Marketing	BA	HN75	3FT
Computer Aided Product Design	HND	27WH	2FT
Product Design (Innovation and Ecodesign)	BSc	HW72	3FT
Credit Accumulation Modular Scheme	BA/BSc	Y600	3FT
University of East London			
Product Design	BSc	H764	4FT
Product Design (Extended)	BSc	H765	4FT
University of Glamorgan			
Product Design	BA	E230	3FT
Product Design	BSc	H3W2	3FT
Product Design	BA	W2H3	3FT
University of Glasgow			
Product Design Engineering (BEng)	BEng	H3W2	4FT
Product Design Engineering (Fast Track)	MEng	H3WF	4FT
Product Design Engineering (MEng)	MEng	H3WG	5FT
Product Design	MEDes	HY73	4FT
Glasgow Caledonian University			
Food Product Design with Management	BA	D4N9	4SW
Integrated Product Design	BA	H772	2FT
Multimedia Visualisation with Product Design	UDip	P4H7	2FT
University of Hertfordshire			
Product Design	BA	E772	3FT
Product Design (Extended)	BA	E778	4FT
Product Engineering	BEng	H700	3FT
Product Engineering	MEng	H701	4FT
Product Engineering (Extended)	BEng	H708	4FT
Also available at these sites: West Herts College, Barnet College			
Product Design	BA	H772	3FT
Product Design (Extended)	BA	H778	4FT
The University of Huddersfield			
Product Design	BA	EW72	3FT
Product Design	DipHE	EW7F	2FT
Product Development	BSc	H3N9	3FT
Product Innovation, Design and Development	BSc	H772	3FT
Product Design	BA	HW72	3FT
Product Design	DipHE	HW7F	2FT
Kent Institute of Art & Design			
Product Design	BA	E235	3FT
Product Design	BA	W235	3FT
Kingston University			
Product & Furniture Design	BA	E235	3FT
University of Lincolnshire and Humberside			

Comp (Games, Simulation & VR) & Product Des Tech	BA/BSc	GH57	3FT
Computing (Internet Technologies) & Product Des	BA/BSc	GH5R	3FT
Interactive Design & Product Design Technology	BA/BSc	GH5T	3FT
Comp(Network Syst Support/Mgt) & Product Des Tec	BA/BSc	GH67	3FT
Comp(Multimedia Systems Dev) & Product Des Tech	BA/BSc	GH6R	3FT
Engineering (Product Design Technology)	BSc	H660	3FT
Computing and Product Design Technology	BA/BSc	HG75	3FT
Information Technology & Product Des Technology	BA/BSc	HG7M	3FT
Product Des Technology & Telecommunication Tech	BA/BSc	HH76	3FT
Architectural Technology and Product Design Tech	BA/BSc	HK72	3FT
Applied Social Sci and Product Design Technology	BA/BSc	HL73	3FT
Business and Product Design Technology	BA/BSc	HN71	3FT
Accountancy and Product Design Technology	BA/BSc	HN74	3FT
Electronic Commerce & Product Design Technology	BA/BSc	HN75	3FT
Human Resource Mgt and Product Design Technology	BA/BSc	HN76	3FT
Marketing and Product Design Technology	BA/BSc	HN7M	3FT
Museum & Exhibition Design & Product Design Tech	BA/BSc	HP71	3FT
Advertising and Product Design Technology	BA/BSc	HP73	3FT
Media Technology and Product Design Technology	BA/BSc	HP74	3FT
Multimedia Electronic Tech & Product Des Tech	BA/BSc	HP75	3FT
European Studies and Product Design Technology	BA/BSc	HT72	3FT
Modern Languages and Product Design Technology	BA/BSc	HT79	3FT
Fine Art and Product Design Technology	BA/BSc	HW71	3FT
Animation and Product Design Technology	BA/BSc	HW72	3FT
Phonic Art and Product Design Technology	BA/BSc	HW73	3FT
Product Design Technology and TV and Film Design	BA/BSc	HW75	3FT
Interior Design and Product Design Technology	BA/BSc	HW79	3FT
Graphic & Digital Art and Product Design Tech	BA/BSc	HW7F	3FT
Graphic Design and Product Design Technology	BA/BSc	HW7G	3FT
Illustration and Product Design Technology	BA/BSc	WH27	3FT

Liverpool John Moores Univ

Product Design Engineering	BSc	H770	3FT
Product Design and Digital Modelling	BDes	H771	3FT
Business and Product Design	BA/BSc	NH17	3FT

London Guildhall University

Product Development & Manufacture & Psychology	Mod	CJ84	3FT
Mathematics & Product Development & Manufacture	Mod	GJ14	3FT
Computing & Product Development & Manufacture	Mod	GJ54	3FT
Business IT & Product Development & Manufacture	Mod	GJ74	3FT
Multimedia Systems & Product Development & Manuf	Mod	GJM4	3FT
Economics & Product Development & Manufacture	Mod	JL41	3FT
Product Development & Manufacture & Sociology	Mod	JL43	3FT
Product Develop & Manuf & Social Policy & Mgt	Mod	JL44	3FT
Business Economics & Product Development & Manuf	Mod	JL4C	3FT
Politics & Product Development & Manufacture	Mod	JM41	3FT
Law & Product Development & Manufacture	Mod	JM43	3FT
Development Studies & Product Develop & Manuf	Mod	JM49	3FT
International Relations & Prod Develop & Manuf	Mod	JM4C	3FT
Product Development & Manuf & Public Policy	Mod	JM4D	3FT
Criminology & Product Development & Manufacture	Mod	JM4H	3FT
Business & Product Development & Manufacture	Mod	JN41	3FT
Financial Services & Product Development & Manuf	Mod	JN43	3FT
Accounting & Product Development & Manufacture	Mod	JN44	3FT
Marketing & Product Development & Manufacture	Mod	JN45	3FT
Product Development & Manufacture & Transport	Mod	JN49	3FT
Product Development & Manufacture & Taxation	Mod	JN4H	3FT
Insurance & Product Development & Manufacture	Mod	JN4J	3FT
Communications & Product Development & Manuf	Mod	JP44	3FT
English Studies & Product Development & Manuf	Mod	JQ43	3FT
American Studies & Product Development & Manuf	Mod	JQ44	3FT
French & Product Development & Manufacture	Mod	JR41	4FT
German & Product Development & Manufacture	Mod	JR42	4FT
Product Development & Manufacture & Spanish	Mod	JR44	4FT
European Studies & Product Development & Manuf	Mod	JT42	3FT
Asia Studies & Product Development & Manufacture	Mod	JT45	3FT
Modern History & Product Development & Manuf	Mod	JV41	3FT
Fine Art & Product Development & Manufacture	Mod	JW41	3FT

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Design Studies & Product Development & Manuf	Mod	JW42	3FT
Product Development & Manuf & 3D/Spatial Design	Mod	JW4F	3FT
Banking & Product Development & Manufacture	Mod	NJ34	3FT
Investment & Product Development & Manufacture	Mod	NJJ4	3FT
Modular Programme	Mod	Y400	3FT
The London Institute			
Product Design	BA	E230	3FT
Product Development for the Fashion Industries	BA	E470	4SW
Product Development for the Fashion Industries	BA	J470	4FT
Loughborough University			
Product Design and Manufacture	BEng	H770	3FT
Product Design and Manufacture (4 Yr SW)	BEng	H771	4SW
Product Design and Manufacture (4 Yr MEng)	MEng	H772	4FT
Product Design and Manufacture (5 Yr MEng)	MEng	H773	5SW
University of Luton			
Product Design	BA	E231	3FT
Product Engineering	BEng	H771	3FT
Product Design	BA	W231	3FT
Umist			
Fibre Technology and Product Design	MTec	HJ74	4FT
Manchester Metropolitan Univ			
Clothing Product Development	BSc	E472	4SW
Clothing Product Development	BSc	J472	4SW
Consumer Product Marketing and Technology	BSc	N510	3FT
Consumer Product Marketing and Technology	HND	015N	2FT
Consumer Product Marketing & Techn Foundation	BSc	N518	4FT
Consumer Product Sciences	BSc	N750	3FT
Consumer Product Sciences	HND	057N	2FT
Consumer Product Sciences Foundation	BSc	N758	4FT
Middlesex University			
Product Design	BA	E230	3FT
Product Design with Italian	BA	E2R3	3FT
Product Design with Spanish	BA	E2R4	3FT
Product Design	BA	W230	3FT
Product Design Foundation	BA/BSc	W238	1FT
Product Design with Italian	BA/BSc	W2R3	3FT
Product Design with Spanish	BA/BSc	W2R4	3FT
Product Design plus minor subject	BA	W2YK	3FT
Napier University			
Engineering Product Design	BSc	H760	3FT
Product Design Development	BSc	H761	3FT
Management and Product Design	BSc	NH17	3FT
University College Northampton			
Product Design (Route B)	HND	27WE	2FT
Product Design (Route B)	BSc	EW72	3FT
Product Design (Route A)	HND	27WH	2FT
Product Design (Route A)	BSc	HW72	3FT
University of North London			
Electronic Product Technology	BSc	H690	3FT
Electronic Product Technology	HND	096H	2FT
Electronic Product Technology and Marketing	Mod	HNP5	3FT
Combined Honours	BSc	Y100	3FT
Univ of Northumbria			
3D Design: Furn and Ints/Jewel and Fine Prod	BA	EW62	3FT
Nottingham Trent University			
Applied Nutrition and Product Development	BSc	BD44	3FT
Furniture and Product Design	BA	E230	4SW
Product Design	BA/BSc	E771	3FT

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Product Design	BA/BSc	H771	3FT
Furniture and Product Design	BA	W230	3FT
Oxford Brookes University			
Computer Aided Product Design	BSc	H160	3FT
Computer Aided Product Design	HND	27WH	2FT
University of Paisley			
Product Design and Development	BSc	H770	3FT
University of Plymouth			
Food Quality with Product Develop and Nutrition	BSc	D401	3FT
Three Dimensional Design-Product Design	BA	E230	3FT
Three Dimensional Design-Product Design	BA	W230	3FT
University of Portsmouth			
Product Design and Innovation	BSc	H771	3FT
Computer Aided Product Design	BSc	H7G5	3FT
Ravensbourne College of Design and Communication			
Product Design	BA	E230	3FT
Furniture and Related Product Design	BA	E231	3FT
Reading College and School of Arts & Design			
Product Design	HND	032E	2FT
Product Design	HND	032W	2FT
The Robert Gordon University			
Consumer Product Management	BSc	N980	3FT
University of Salford			
Product Design and Development	BSc	E230	3FT
Product Design and Development	BSc	W230	3FT
Sheffield Hallam University			
Industrial Design (Product)	BA	E230	3FT
Industrial Design (Product)	BA	W230	3FT
Somerset College of Arts and Technology			
Design (Product Design and Manufacture)	HND	045E	2FT
Design (Product Design and Manufacture)	HND	045J	2FT
Southampton Institute			
Product Design with Marketing	BA	E2N5	3FT
Product Design with Marketing (with foundation)	BA	E2NM	4FT
Product Design with Marketing	BA	W2N5	3FT
Product Design with Marketing (with foundation)	BA	W2NM	4FT
South Bank University			
Engineering Product Design	BSc	H770	3FT
Sports Product Design	BSc	H7B6	3FT
Staffordshire University			
Design: Product Design (includes Level Zero)	BA	E228	4FT
Design: Product Design	BA	E230	3FT
Product Design Technology	BA	E231	3FT
Design: Product Design (includes Semester Zero)	BA	E248	3FT
Design: Decorative Products (inc Level Zero)	BA	E261	4FT
Design: Decorative Products (inc Semester Zero)	BA	E262	3FT
Product Design Technology	BSc	H771	3FT
Design: Product Design (includes Level Zero)	BA	W228	4FT
Design: Product Design	BA	W230	3FT
Product Design Technology	BA	W231	3FT
Design: Product Design (includes Semester Zero)	BA	W248	3FT
Design: Decorative Products (inc Level Zero)	BA	W261	4FT
Design: Decorative Products (inc Semester Zero)	BA	W262	3FT
The University of Strathclyde			

Product Design Engineering	MEng	H770	5FT
Product Design Engineering	BEng	H771	4FT
University of Sunderland			
Innovation and Product Design Management (Found)	BSc	HN7C	4FT
Innovation and Product Design (Foundation)	BSc	HN7D	4FT
Innovation and Product Design	BSc	HW7F	3FT
Innovation and Product Design Management	BSc	NH17	3FT
Surrey Inst of Art & Design, University College			
Product Design (Sustainable Futures)	BA	E2H7	3FT
Product Design (Sustainable Futures)	BA	W2H7	3FT
University of Sussex			
Product Design	BSc	H770	3FT
University of Wales Swansea			
Product Design and Manufacture	BEng	H770	3FT
Swansea Institute of He			
Product Design	BSc	E770	3FT
Product Design	BSc	E778	4FT
Product Engineering	MEng	H100	4FT
Product Design	BSc	H770	3FT
Product Design	BSc	H778	4FT
University of Teesside			
Computer Aided Product Design	HND	27WH	2FT
The University of Ulster			
Graphic and Product Design	BA	E230	3FT
Graphic and Product Design	DipHE	E231	2FT
University College Warrington			
Media St (Comm Music Prod) and Bus Mgt and IT	BA	NP1L	3FT
Media St (TV Product) and Leisure Mgt (Tourism)	BA	NP7K	3FT
Media St (Radio Prod) and Leisure Mgt (Tourism)	BA	NP7L	3FT
Media St (Television Prod) and Bus Mgt & IT	BA	NPC4	3FT
Media Studies (Radio Prod) with Sport Studies	BA	P4BP	3FT
Media Studies (Radio Prod) with Leisure Mgt	BA	P4NT	3FT
Media St (Comm Music Prod) with Bus Mgt and IT	BA	P4W3	3FT
Media St (Radio Prod) with Business Mgt and IT	BA	P4W5	3FT
Media Studies (Comm Music Prod) with Perf Arts	BA	P4WH	3FT
Media Studies (Comm Music Prod) with Leisure Mgt	BA	P4WJ	3FT
Media Studies (TV Prod) with Performing Arts	BA	P4WK	3FT
Media Studies (Radio Prod) with Performing Arts	BA	P4WL	3FT
Media Studies (TV Prod) with Business Mgt and IT	BA	P4WM	3FT
Media Studies (TV Prod) with Leisure Management	BA	P4WN	3FT
Media St (Radio Prod) with Professional St (Ed)	BA	P4XX	3FT
Media St (TV Prod) and Leisure Mgt (Lic Ent)	BA	PN47	3FT
Media St (Com Mus Prod) & Leisure Mgt (Lic Ent)	BA	PN4R	3FT
Media St (Radio Prod) and Leisure Mgt (Lic Ent)	BA	PN4T	3FT
Media St (Radio Prod) and Leisure Mgt (Out Rec)	BA	PNKR	3FT
Media St (TV Prod) and Leisure Mgt (Outdoor Rec)	BA	PNL7	3FT
Media Studies (TV Prod) and Leisure Mgt (Sport)	BA	PNLR	3FT
Media St (Radio Prod) and Leisure Mgt (Sport)	BA	PNLT	3FT
Warwickshire College, Royal Leamington Spa & M M			
3D Design (Industrial Product Design)	HNC	262E	1FT
Design (3D Design) Industrial Product Design	HND	062E	2FT
West Herts College, Watford			
Media Prod Mgt-Moving Image (TV,Film,Video Prod)	BA	E4W5	3FT
Media Prod Mgt-Still Image(Photo & Digital Imag)	BA	E4WM	3FT
Media Prod Mgt-Moving Image (TV,Film,Video Prod)	BA	P4W5	3FT
University of Westminster			
Product Design Engineering	BSc	H770	3FT
Product Design Engineering with foundation	BSc	H778	4FT

University of Wolverhampton			
Food Product Design (Stafford)	HND	034D	2FT
Industrial (Product) Design	BA	E231	4SW
Combined Degrees	Mod	E401	3FT
Computer Aided Product Design	BSc	EW7F	3FT
Product Engineering	BSc	H700	3FT
Computer Aided Product Design	BSc	HW72	3FT
Computer Aided Product Design	BSc	HW7F	3FT
Industrial (Product) Design	BA	W231	4SW
Combined Degrees	Mod	Y401	3FT

Search results:
349 product courses in all regions for 2000 year of entry.

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Last Updated 2000-03-08

	Course Level	Course Code	Course Length	Campus Codes
Anglia Polytechnic University				
Computer Aided Product Design	HND	27WH	2FT	
Also available at this site: Chelmsford				
Computer Aided Product Design	BSc	HW72	3FT	
Also available at this site: Chelmsford				
Bolton Institute of He				
Leisure Computing Technology and Product Design	Mod	GH7T	3FT	
Computer Aided Product Design	BSc	HW72	3FT	
Computer Aided Product Design	BSc	HW7F	4FT	
Bournemouth University				
Computer Aided Design (Products)	HND	161H	2FT	
University of Derby				
Computer Aided Product Design	HND	27WH	2FT	
University of Lincolnshire and Humberside				
Comp (Games, Simulation & VR) & Product Des Tech	BA/BSc	GH57	3FT	
Computing (Internet Technologies) & Product Des	BA/BSc	GH5R	3FT	
Comp(Network Syst Support/Mgt) & Product Des Tec	BA/BSc	GH67	3FT	
Comp(Multimedia Systems Dev) & Product Des Tech	BA/BSc	GH6R	3FT	
Computing and Product Design Technology	BA/BSc	HG75	3FT	
London Guildhall University				
Computing & Product Development & Manufacture	Mod	GJ54	3FT	
Oxford Brookes University				
Computer Aided Product Design	BSc	H160	3FT	
Computer Aided Product Design	HND	27WH	2FT	
University of Portsmouth				
Computer Aided Product Design	BSc	H7G5	3FT	
University of Teesside				
Computer Aided Product Design	HND	27WH	2FT	
University of Wolverhampton				
Computer Aided Product Design	BSc	EW7F	3FT	
Computer Aided Product Design	BSc	HW72	3FT	
Computer Aided Product Design	BSc	HW7F	3FT	

Search results:
20 computing and product courses in all regions for 2000 year of entry.

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Appendix II

UNIVERSITY OF WOLVERHAMPTON
SCHOOL OF ENGINEERING AND THE BUILT ENVIRONMENT

MODULE GUIDE

Module	**CM1000 PRODUCT DESIGN AND DEVELOPMENT**		
Semester 1	1997/98		
Pre-requisite:	None	Co-requisite:	None
Level:	1	Credit Value:	15
Timetable Slot:	Tue am	Location:	Telford site

MODULE LEADER: Tony Felton
Room SB121 Tel 3852

Aim: To establish the basic principles of design methodology and develop experience in practical product design situations.

Learning Outcomes

MODEL B: By successful completion of the module students will be able to:

SUBJECT SPECIFIC OUTCOMES (SSO)

OUTCOME (I): Apply the principles of design methodology to the design process.
SCOPE: Design methodologies, systematic design approach applied to product design.
ASSESSMENT COMPONENT(S): Component 1

OUTCOME (II): Make use of anthropometrics and ergonomics in product design.
SCOPE: Anthropometric data, ergonomics etc in the design process
ASSESSMENT COMPONENT(S): Component 2

OUTCOME (III): Integrate aesthetics / style and packaging into product design.
SCOPE: Aesthetics in product design, styling, use of models, packaging for product design
ASSESSMENT COMPONENT(S): Component 2

PERSONAL TRANSFERABLE SKILLS (PTS)

OUTCOME 1: (2) Organise
SCOPE: Recognise task demands and manage time effectively.
ASSESSMENT COMPONENT(S): Component 2

OUTCOME 2: (5) Act Independently
SCOPE: Develop autonomy, initiative, self motivation; demonstrate decision making and problem-solving skills
ASSESSMENT COMPONENT(S): Component 2

OUTCOME 3:	
SCOPE:	
ASSESSMENT COMPONENT(S):	

GENERIC ACADEMIC OUTCOME/CRITERIA (GAO/C)

OUTCOME A:	D Analyse
SCOPE:	Identify ideas, concepts and apply standard theories.
ASSESSMENT COMPONENT(S):	Component 1

OUTCOME B:	F Think creatively
SCOPE:	Propose solutions for Engineering Problems with limited Technical Constraints.
ASSESSMENT COMPONENT(S):	Component 2

Tuition: Tue am: 2 hour lecture and 1 hour tutorial (some practical time may be required)

Private Study 7 hours per week

Teaching Methods: Some formal lectures, some student centred teaching involving group activity, case studies of product designs using slides and videos.

LECTURE PROGRAMME:

Lecture	Title or Topics Covered
1	**Design Methodology** Morphology of Design. Detailed examination of the designers methodology to identify and solve problems.
2	**Design Methodology** Anatomy of Design. Product life cycle from conception to retirement.
3	**The Systematic Design Approach** Primary need, iterative design procedure, specification.
4	**The Systematic Design Approach** Innovative design, group stimulus, brainstorming. Design for compactibility, for recycling.
5	**Anthropometrics and Ergonomics** The use of anthropometric data, the concept of the 'average' person
6	**Anthropometrics and Ergonomics** The man/machine relationship, ergonomics in the design process, types of display, types of control.
7	**Aesthetics** Aspects of aesthetics applied to product design, styling.
8	**Aesthetics** Case studies in aesthetic design.
9	**Models and modelling** The use of models in the design process
10	**Models and modelling** Types of models - qualitative, quantitative.
11	**Packaging** Packaging for marketing, cost effectiveness
12	**Packaging** Product protection, environmental factors, recycling etc
13	**Review of module.**

21

ASSESSMENT: The overall grade is determined by weighting the elements of the assessment into two components as follows:

Assessment Details

ASSESSMENT COMPONENTS							
	DESCRIPTION	OUTCOMES			PASS/ FAIL *	WEIGHTING *	HAND-IN DATE
		SSO	PTS	GAC			
1	Component 1: End of semester examination.	1		B		50%	End of module
2	Component 2: Design and make project	11 111	1,2	A		50%	Week 12
3							

To pass the module it is normally necessary to achieve a minimum grade of D5 in **each** of the two components of the assessment as shown above.

Examination: a two hour unseen paper.
Assignment: this will involve a design and make product which may involve packaging considerations.

Practical work: this consists of workshop sessions to acquire the necessary skills to undertake the realisation of the assignment.

Any written/practical work for assessment should be handed in to the registry by the due date, as indicated by the Lecturer, and a dated receipt obtained.

If you have a valid reason for late submission then **written** permission must be obtained from the Module Leader **before** the due date on form AAO33.

PRIVATE STUDY TIME
Each week you will need to tackle some of the design problems given and satisfy yourself that you are reasonably happy with the topic and that you can apply it to the design process. Once the assignment is set you will need to ensure that you are making progress to complete the assignment before the cut- off date.
The guided reading, given below, offers you the opportunity to either do some background reading around the subject or as a source of reference for the topic.

GUIDED READING:
The Engineering Design Process, B Hawkes and R Abinett.
Design Graphics, David Fair and Marilyn Kenny.
Engineering Design, George Dieter, McGraw Hill.
Packaging Design, Roth, Reinhold.
In addition there are a number of books in the library on the design process, anthropometrics, ergonomics, modelling and packaging.
PS You are reminded of the importance of checking that you are officially registered for this module otherwise you will not be awarded a grade. You are also reminded of the consequences of cheating/plagiarism, if in doubt ask the module leader.

A J Felton Sept 99

BSc CAPD STUDENT PLACEMENTS		CAPD\CAPD student placements	
SESSION	COMPANY NAME	COUNTRY	DEPARTMENT
1995/96	Astralite Ltd	UK	
	Automotive Sys Des	UK	
	Bretel Oty	Finland	
	Delft Univ	Netherlands	
	Design Eng Serv	UK	
	Extech Environ	UK	
	Ind Flow Cont	UK	
	Index Ind Des	USA	
	Magneti Marelli	UK	
	Meyer Vi-Tech	UK	
	Mipro Ltd	Finland	
	Munters Ltd	UK	
	Quest Bus Tec	UK	
	Rejlers Ltd	Finland	
	Renold Chain	UK	
	Univ de Minho	Portugal	
	Valor Heating	UK	
	Vivid Image	UK	
	W G Allen	UK	
1996/97	Autodesign	UK	
	British Nuclear Fuels	UK	
	CAD Assist	UK	
	D.E.S. Ltd	UK	
	Destec Ltd	UK	
	Fletcher Associates	UK	
	Industrial Flow Control Ltd	UK	
	Magneti Marelli UK Ltd	UK	
	NEC Technologies (UK) Ltd	UK	
	Reckitt & Coleman Products	UK	
	The M.O.D.	UK	
	TSA Advet Ltd	UK	
	Tu Delft	Netherlands	
	Tuchenhagen UK	UK	
	W.G. Allen (B'ham) Ltd	UK	
	XCAD UK Ltd	UK	
1997/98	ACME Gerrard Ltd	UK	
	Arc Partioning	UK	
	Cal Gavin Ltd	UK	
	Cobal Sign Systems Ltd	UK	
	Denso	UK	
	Design & Projects Ltd	UK	
	Design Engineering Services	UK	
	Devonshire House & Assoc Ltd	UK	
	Dowdswell Engineering Co Ltd	UK	
	Equinox	UK	
	GKN Westland	UK	
	Kennemetal Hertel UK Ltd	UK	
	NEC Technologies (UK) Ltd	UK	

	Peerless Stampings	UK	
	Revolution Software Ltd	UK	
	Roush Technologies	UK	
	Scurr & Partners Ltd	UK	
	Tudor Westbaston Sunroofs Ltd	UK	
1998/99	Airborne Development	Netherlands	
	American Hydroponics Inc	USA	Pro Eng
	BHI Net Centre	UK	
	BICC Components Ltd	UK	Design
	Britax Excelsior Ltd	UK	Technical (CAD/CAM)
	Cintique Ltd	UK	Design
	Creative Manufacturing Systems	UK	Design
	Design Engineering Services	UK	
	Gill Air	UK	
	Hydra-Tight Ltd	UK	Human Resources
	IBSEC Ltd	UK	
	Kespar Engineering Ltd	UK	CAD/CAM Modelling
	Magneti Marelli	UK	Production Engineering
	Premises Networks	UK	
	Raytheon Electronics	UK	Design
	SGB Manufacturing	UK	
	Silvaflame Co Ltd	UK	
	Witter Towbars	UK	Design
1999/2000	Majex Projects Ltd	UK	Design
	Robert Bosch Ltd	UK	Industrial Engineering
	Rolls Royce Nuclear Eng Services Ltd	UK	Engineering
	Lucas Aerospace, Fordhouses	UK	Design
	Jaguar	UK	Design/Engineering

University of Wolverhampton
SEBE Engineering Division

Session 1999/2000

FINAL INDUSTRIAL PLACEMENT PERIOD ASSESSMENT

Student: ______________________ **Company:** ______________________

Industrial Supervisor: ______________________

Ratings: 1. Fail 2. Poor 3. Satisfactory 4. Good 5. Very good

						Score
Log Book - content and detail	1	2	3	4	5	____
Social skills - team membership	1	2	3	4	5	____
Self motivation and application	1	2	3	4	5	____
Initiative	1	2	3	4	5	____
Attendance / punctuality	1	2	3	4	5	____
Attitude to authority	1	2	3	4	5	____
Competency with company technology	1	2	3	4	5	____
Knowledge of company systems and procedures	1	2	3	4	5	____
Knowledge of company products / services	1	2	3	4	5	____
Language development / competency (where appropriate)	1	2	3	4	5	____
				Total		____

Remarks:

(Please indicate pass/fail for the student)

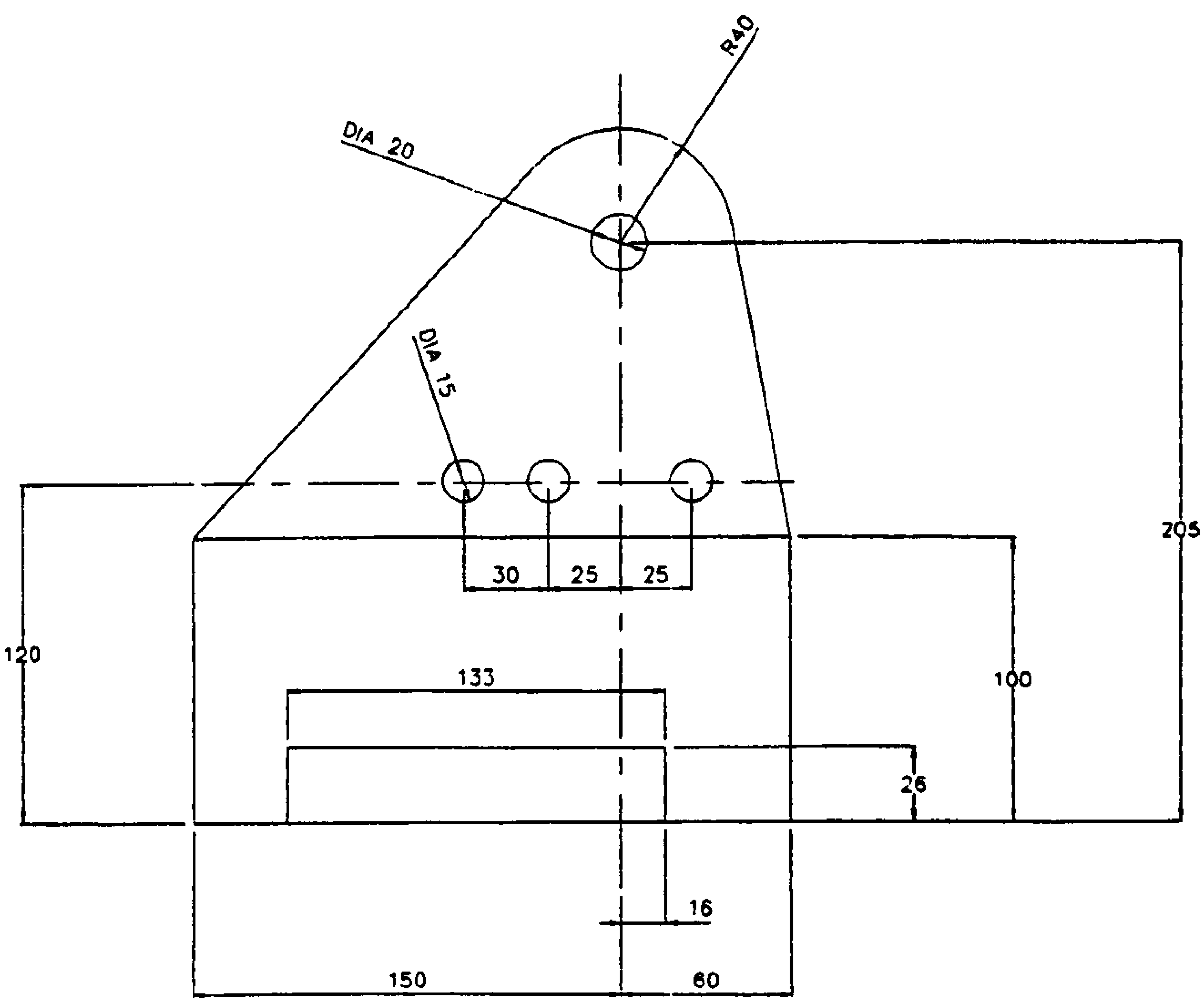
Academic Supervisor's Signature: ______________________ **Date:** ________

Appendix III

AutoCAD Training Document

Developed by the

Engineering Division SEBE



K.B.Garner & A.J.Felton

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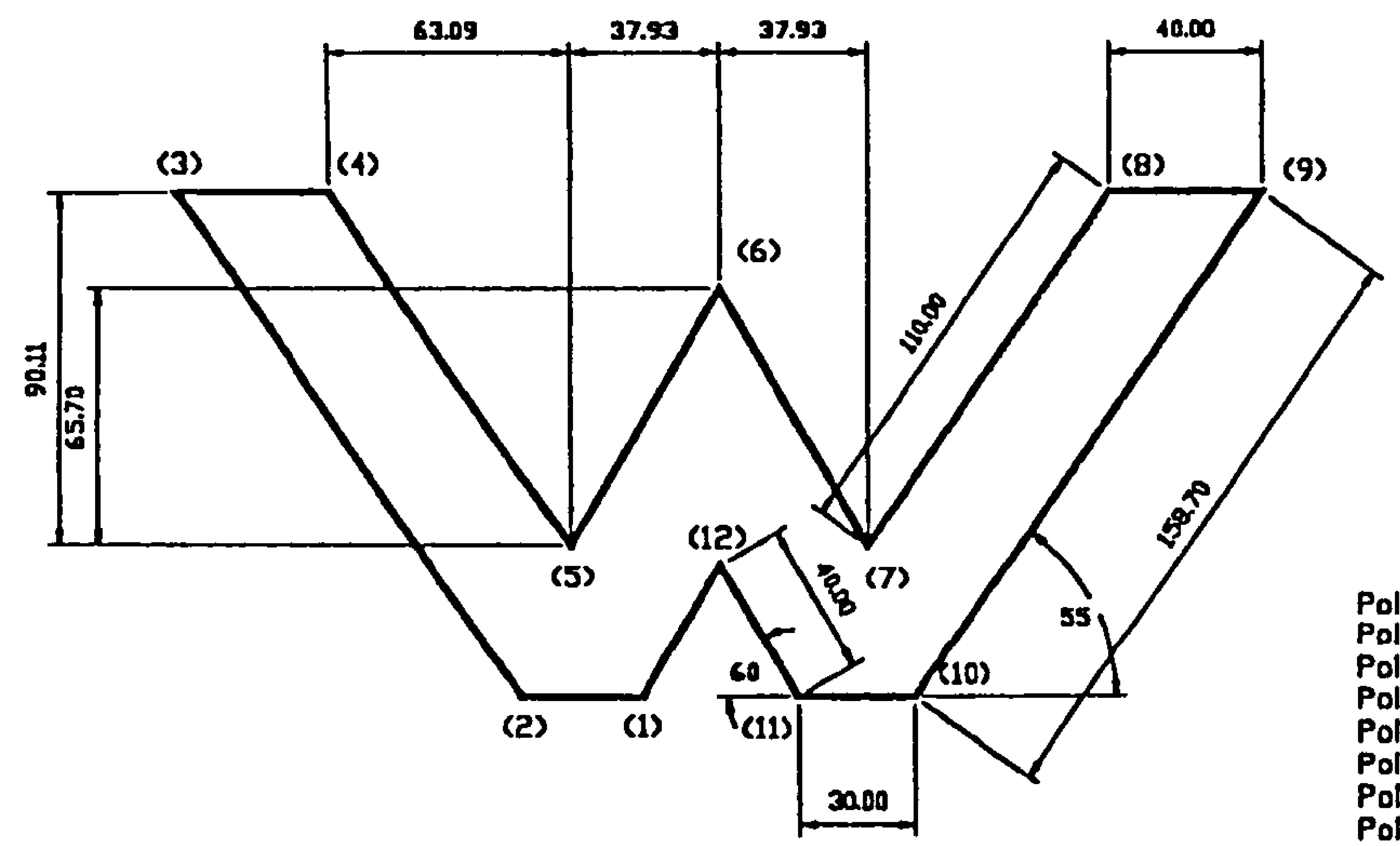
Drawing Units 0,0 - 520,350



Point 1 (190,90)
Point 2 (160,90)
Point 3 (68.97,220)
Point 4 (108.97,220)
Points 4 - 5 Relative Cartesian
Points 5 - 6 Relative Cartesian
Points 6 - 7 Relative Cartesian
Points 7 - 8 Relative Polar
Points 8 - 9 Relative Polar
Points 9 - 10 Relative Polar
Points 10 - 11 Relative Polar
Points 11 - 12 Relative Polar
Close

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Instructions

Draw full size the shape opposite using the given coordinate instructions. This exercise is intended to cover the use of the Autocad absolute, relative cartesian and relative polar coordinate inputs. Note! Dimensions and annotations are not required. Save the drawing onto disc as WW2.DWG

User Comments

The LINE command lets you draw straight lines. You can specify the desired endpoints using either 2D or 3D coordinates, or a combination of the two. If you enter 2D coordinates, AutoCAD uses the current elevation as the Z component of the point.

Format: LINE
From point: Enter a point.
To point: Enter a point.
To point: to end line sequence.

To erase the last line segment without exiting the LINE command, enter "u" at the To point: prompt. You can continue the previous Line or Arc by responding to the From point: prompt with a space or . If you're drawing a sequence of lines that will become a closed polygon, you can reply to the To point: prompt with C to draw the last segment and close the polygon.You can constrain lines to horizontal or vertical by using the ORTHO command.

SCRIPT FILES

The Autocad **SCRIPT** command provides the facility by which sequences of commonly used commands may be chained together and invoked from within the drawing editor. The file containing the commands must be of the ASCII format and the filename must have the extension SCR. Packages such as Windows WRITE can be used to compile the file but when saving, the option "Save As" must be used and the type "Text" selected. The filename extension must be changed to SCR or the file manager used to rename the file afterwards. Remember, that the file content must satisfy all the normal Autocad responses.

The **SCRIPT** command causes commands to be read from the specified script file.

Format: **SCRIPT**
Script file <default>: Enter the script filename.

AutoCAD reads commands from the script file, until one of the following events occurs:

It reaches the end of the file.

You enter a character -- preferably -- from the keyboard.

A command error occurs.

Note: If the script is terminated early due to a command error or by keyboard entry, it can be resumed using the RESUME command.

The RSCRIPT command can be inserted in the script file to restart the script from the beginning.

Exercise 1.
Create and run an Autocad script file based on the Command List shown opposite.

Exercise 2.
Develop a script file to reproduce the earlier WW2.DWG drawing.

Exercise 3.
Develop two script files to set up A4 Horizontal and Vertical drawing sheets including borders and Name/Title blocks.

```
limits
0,0
297,210
zoom
all
line
40,50
90,50
90,100
40,100
40,50

line
110,50
@50,0
@0,50
@-50,0
@0,-50

line
180,50
@50<0
@50<90
@50<180
@50<-90

line
60,120
@60,0
@-30,51.96
@-30,-51.96


150,120
@60<0
@60<120
@60<240
```

SNAP & GRID

Snap and Grid are two partner tools that can be used to assist in geometry creation. Both commands can work independently of each other so it is quite possible to have a grid of 10 whilst snapping to 7 which is clearly a nonsense. However, this feature does allow for variations such as a grid of 10 operating with a snap setting of 5. This often prevents the screen being clogged with grid locations whilst still allowing intermediate locations to be selected. Note! The co-ordinate display can be used to provide an indication of line lengths and angles.

Exercise: Using the Grid and Snap commands reproduce the boxes and triangles drawing .

GRID

The **GRID** command controls the display of a grid of alignment dots to help you place objects in drawings.

Format: **GRID**
Grid spacing(X) or ON/OFF/Snap/Aspect
<current>:

Options
Grid Spacing(X)
A simple number sets grid spacing in drawing units. A number followed by "X" (e.g., "2X") sets the grid spacing to a multiple of the current snap resolution. A value of zero locks the grid spacing to the current snap resolution.
ON Turns grid on with previous spacing.
OFF Turns grid off.
Snap Locks the grid spacing to the current snap resolution (same as a spacing value of zero).
Aspect Permits a grid with different horizontal and vertical spacing.

Note: You can also turn GRID on and off using the F7 key or CTRL+G.

SNAP

The **SNAP** command lets you control the snap resolution, the spacing of an imaginary grid of dots with which newly designated points must align. You can alter the resolution or turn it off entirely forfreestyle drawing.

Format: SNAP
Snap spacing or
ON/OFF/Aspect/Rotate/Style <current>:

Options
Snap Spacing
Sets alignment spacing.
ON Aligns designated points.
OFF Does not align designated points.
AspectSets different X/Y snap resolution.
RotateRotates snap grid by specified angle, and sets a specified base point for the grid.
Style Sets Snap style to either Isometric or Standard.

Note: Snap can be turned on and off with the F9 key or CTRL+B.

ORTHO

The **ORTHO** command lets you control orthogonal drawing mode. When orthogonal mode, also known as "ortho" mode, is set to ON, movement within the drawing is constrained to the vertical and horizontal axes, as these are defined in the current Snap grid.

Format: ORTHO
OFF/ON <current>:

Options

ON Turns orthogonal mode on.

OFF Turns orthogonal mode off.

Note: When the Snap grid is rotated, Ortho mode rotates accordingly. Also, if the isometric snap style is in effect, Ortho mode is applied to the axis pair associated with the current isometric plane. ORTHO can be turned on and off with the F8 key or CTRL+O.

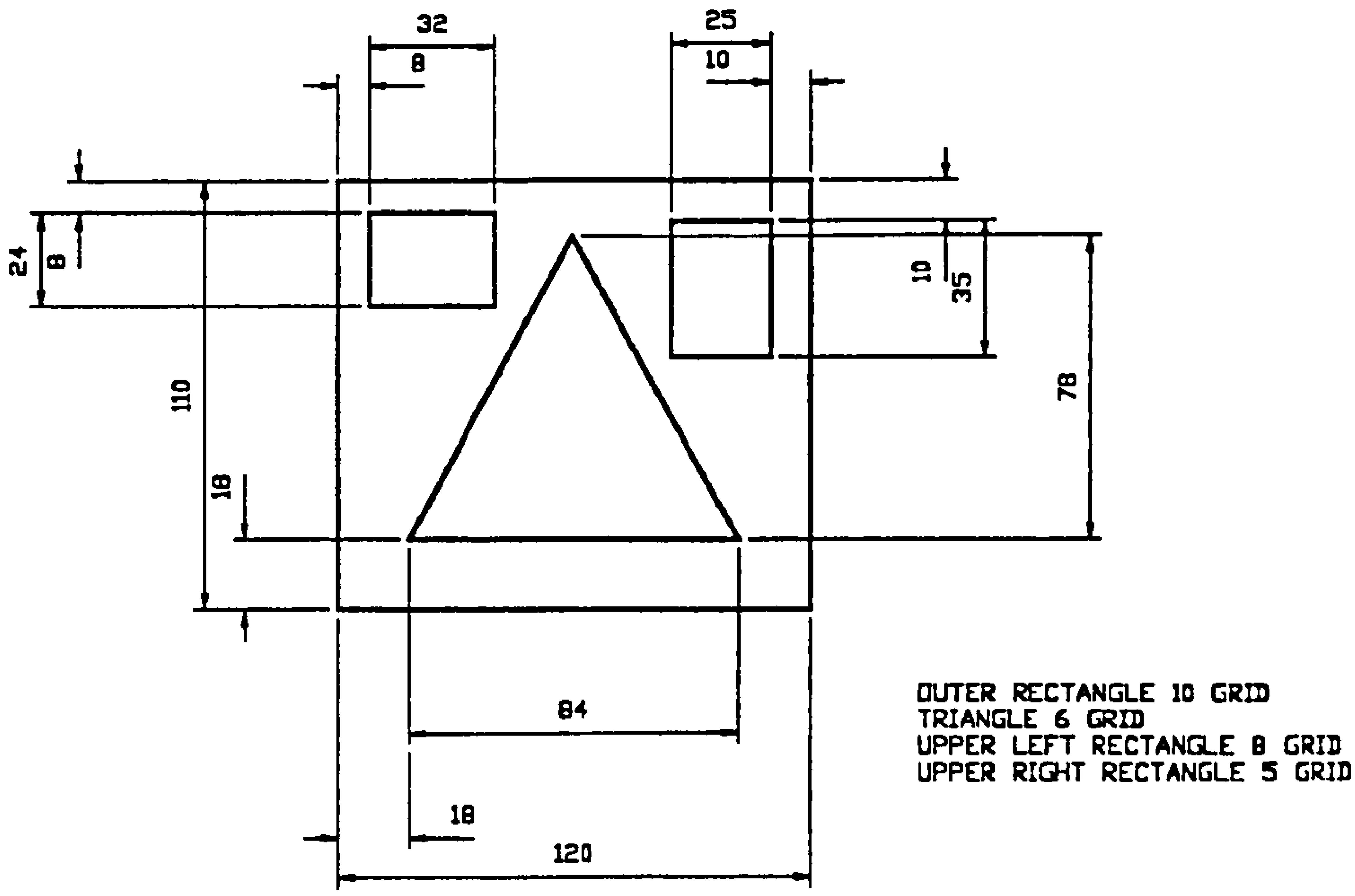
POINT

Autocad has the facility for entering points onto the drawing. Various styles and sizes of points can be added which will remain as part of the finished drawing or which can be used in order to facilitate the construction of the drawing. This might mean the addition of points to identify areas of interest such as datum points or origin locations. Points used in this manner are easily erased prior to saving or plotting the drawing. Geometry can be locked onto points by using the object snap **NODE** locator and their exact position can be determined by using the **ID** command (as can any geometric locations).

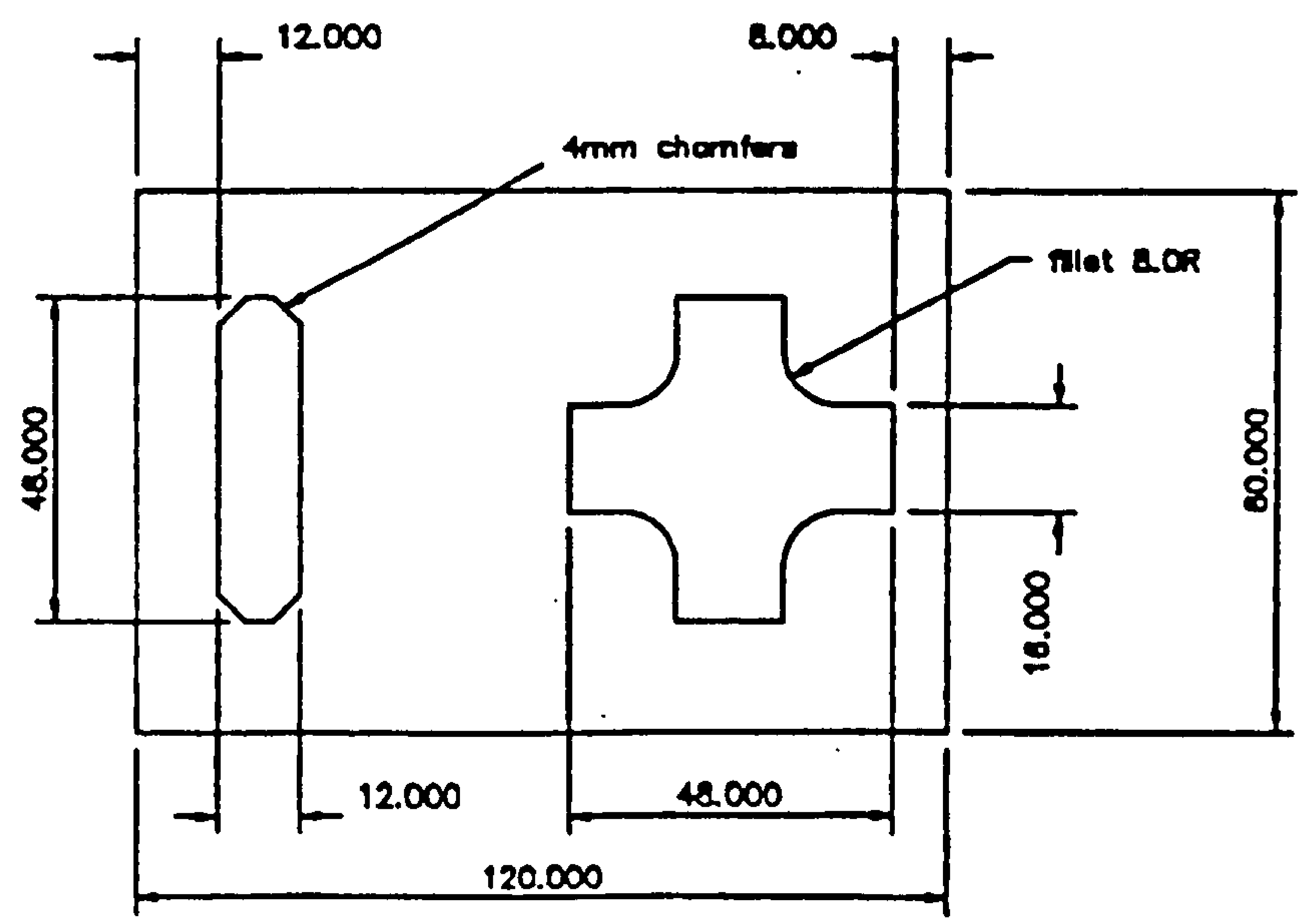
Instructions
Investigate the Autocad help facility on **POINT** and record the key issues below. Use this information to experiment with the **POINT** command. Record a range of point styles and their codes in the boxes provided

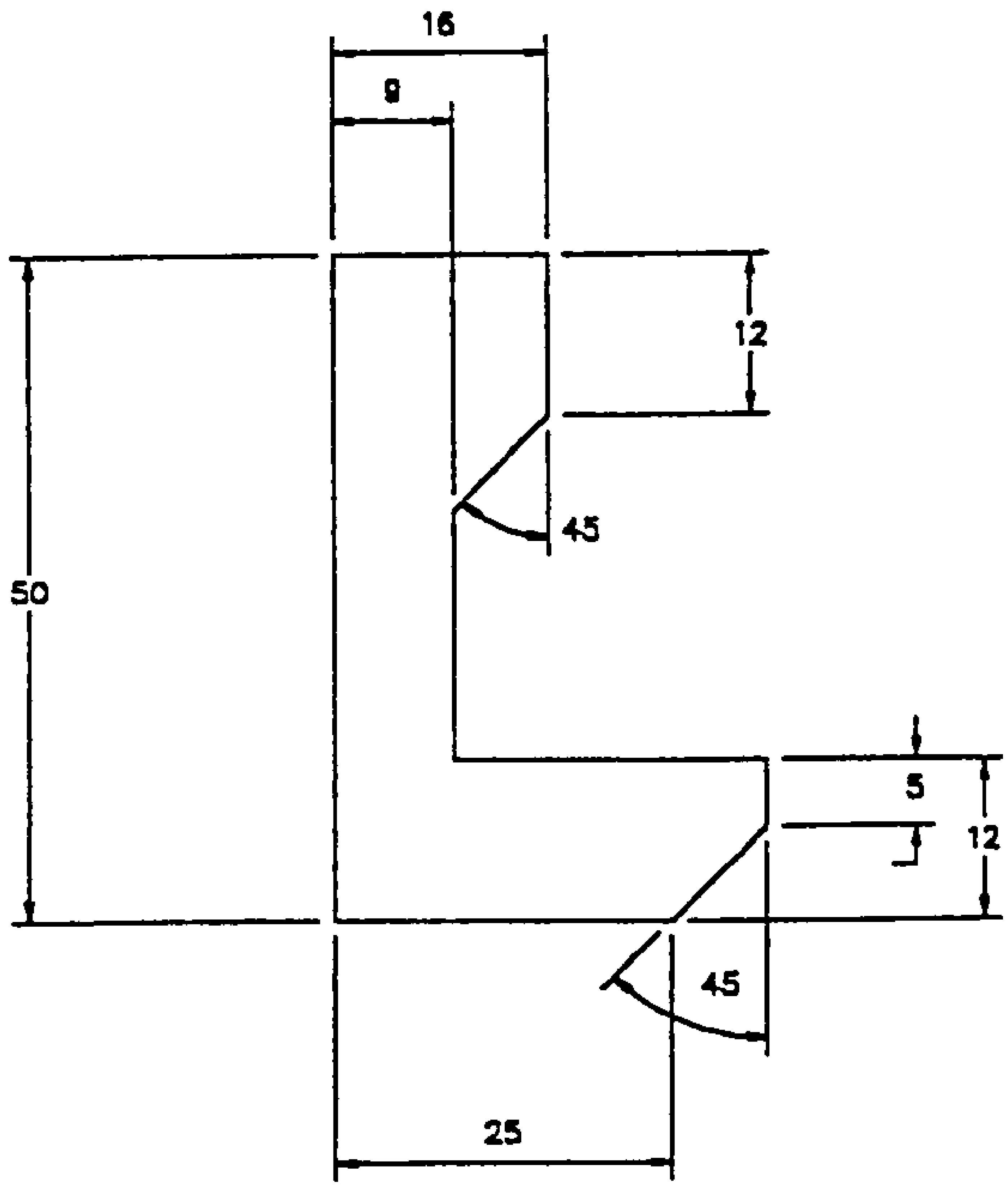
GRID and SNAP Drawing Exercise

Exercise 1.

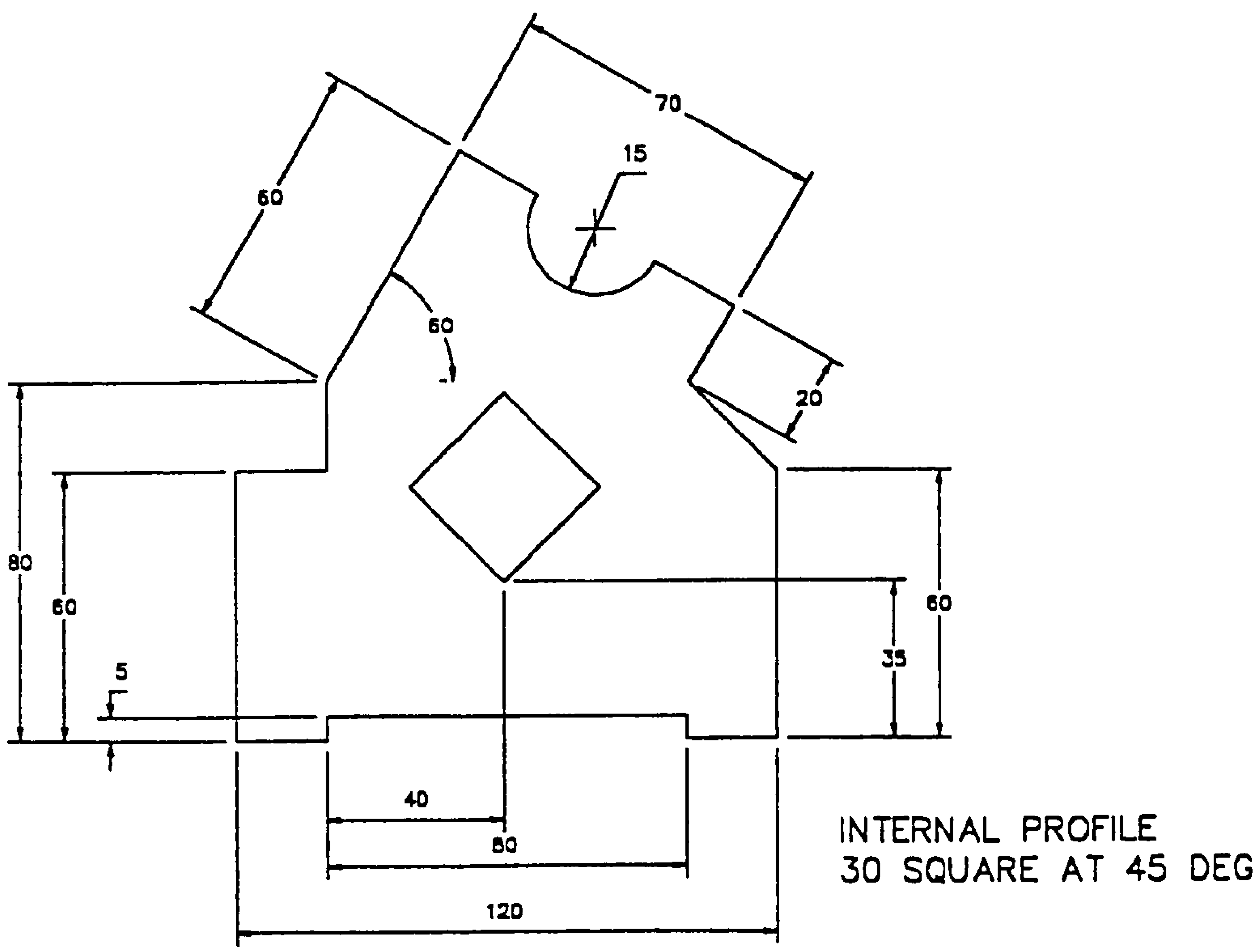


Exercise 2.





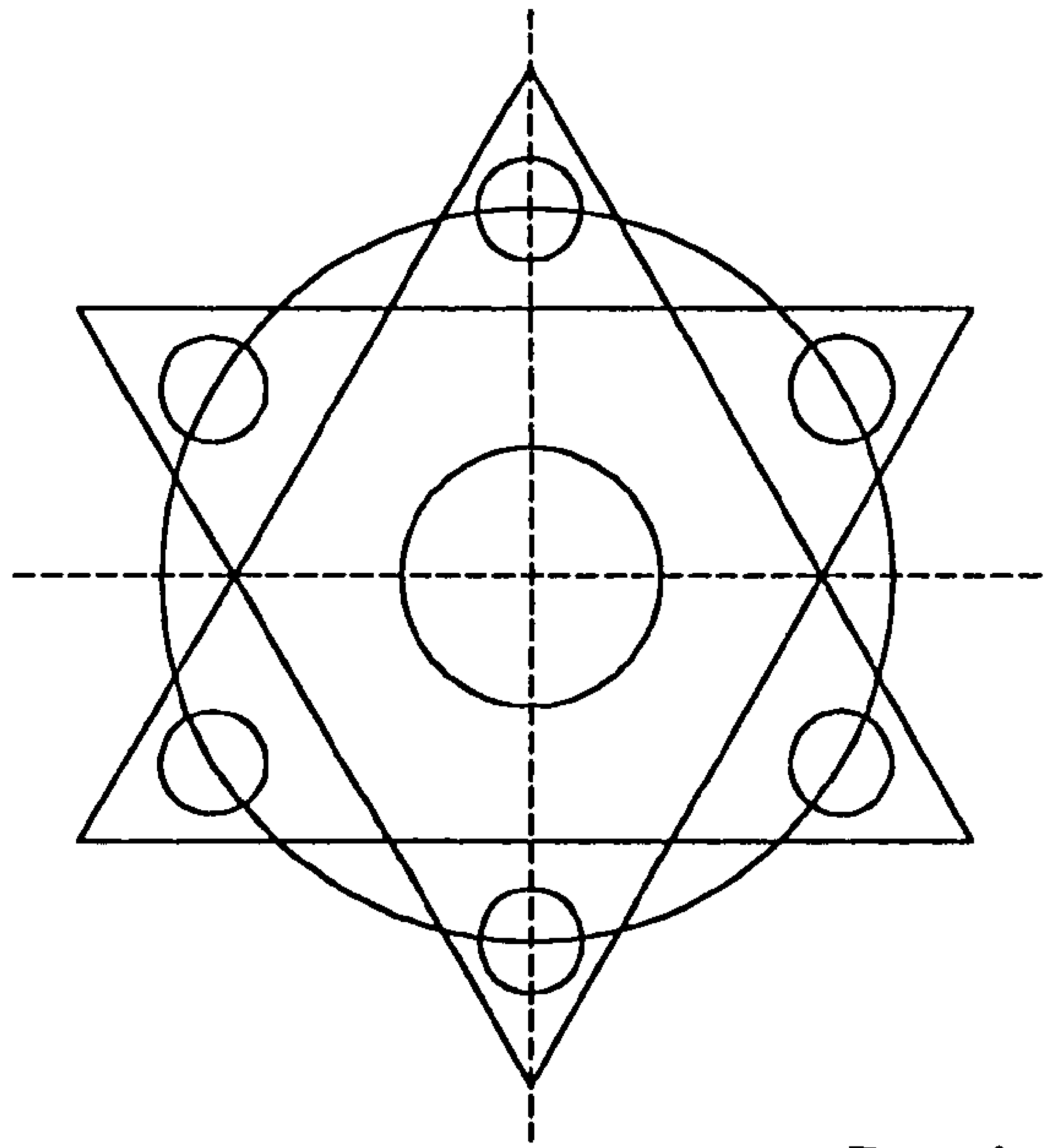
Exercise 3.



Exercise 4.

Erase test piece.

Erase me.



and me.

Drawing: ERASE.DWG

User Comments

When it needs a selection set, AutoCAD issues a Select objects: prompt and replaces the crosshairs of the graphics cursor with a small box. You can automatically use the cursor to pick objects individually or to draw a selection window around them. You can also use keywords and the cursor to select objects in a variety of ways.

Selection Options

(point)	One object selected.	Window	(to the right).
Multiple	Multiple objects selected by pointing.	AUto	Automatic BOX (if pick in empty area) or single object pick.
Last	Last object.	SIngle	One selection (any type).
Previous	All objects in Previous selection set.	Add	Add mode: adds following objects to selection set.
Window	Objects within Window.	Remove	Remove mode: removes following objects from selection set.
Crossing	Objects within or Crossing window.	Undo	Undoes/removes last.
BOX	Automatic Crossing (to the left) or		

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BREAK & TRIM

The **BREAK** command deletes part of a Line, Trace, Circle, Arc, or 2D Polyline, or splits the object into two objects of the same type.

Format: BREAK
Select object:
Enter first point:
Enter second point:

If you break a circle, it changes to an arc by deleting the portion from the first point to the second, going counterclockwise. Breaking a 2D Polyline with non zero width will cause the ends to be cut square.If you select the object by pointing to it, the break is assumed to begin at the selection point. AutoCAD then prompts:

Enter second point (or F for first point):

If you want to begin the break at a point where another object intersects with the object to be broken, choose an unambiguous point to select the object, and then enter F in response to this prompt. You can then select the beginning and ending points of the break.If you want to split the object in two without deleting anything, enter the same point for both the first and second points of the break, by entering @ (last point) for the second point.

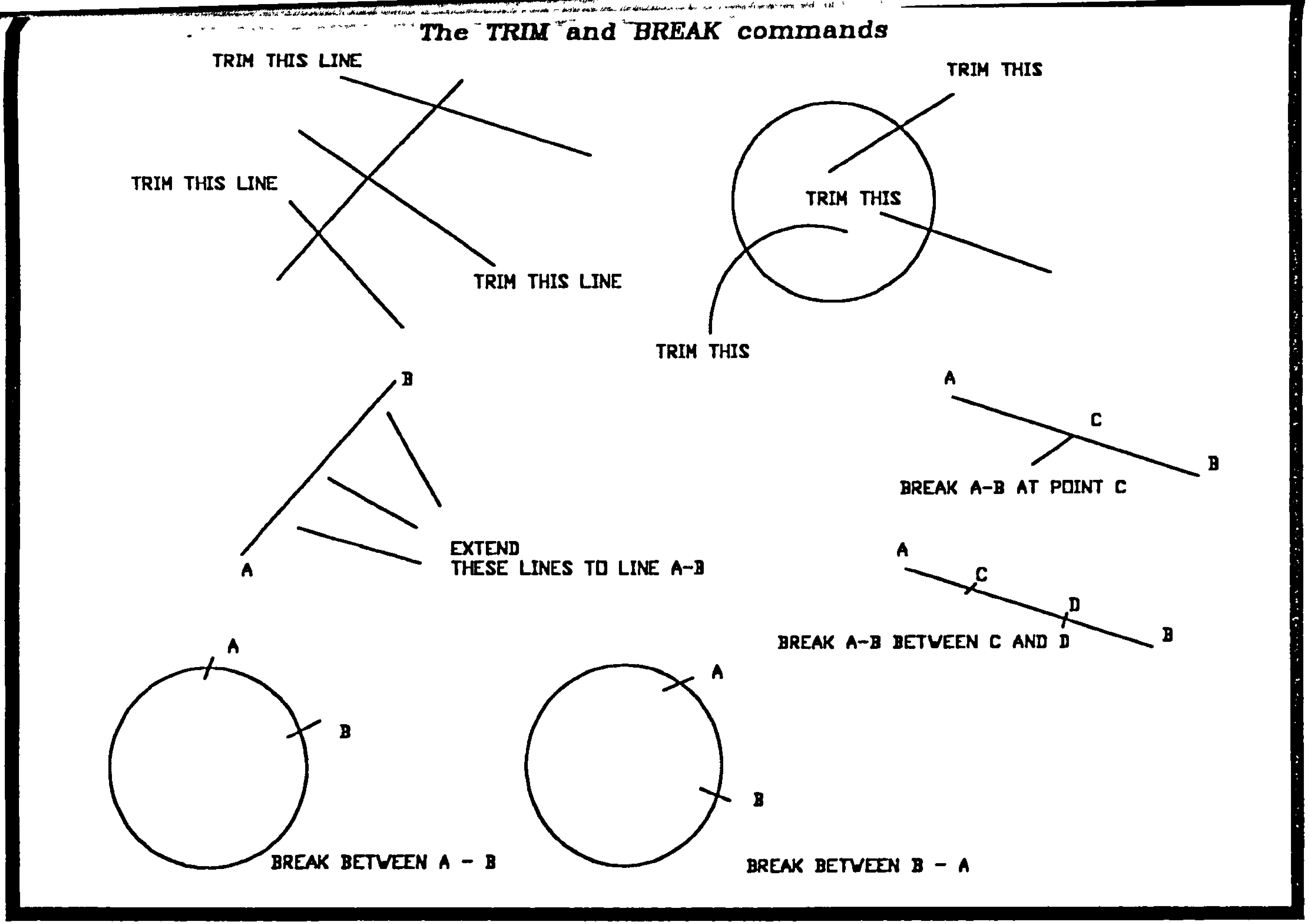
The **TRIM** command lets you trim objects in a drawing so they end precisely at a "cutting edge" defined by one or more other objects in the drawing.

Format: TRIM
Select cutting edge(s)...
Select objects:

Lines, Arcs, Circles, and 2D Polylines (center line of wide Polylines) can serve as boundary objects. All the selected edges are highlighted and will remain highlighted for the rest of the TRIM command. Once you've selected the boundary object(s), AutoCAD prompts:

<Select object to trim>/Undo:

Pick objects to trim by pointing to the part of the object to be trimmed. Respond with U to undo the most recent change, back to the first change made during the current TRIM command. Respond with to end the command.If the selected point is between two intersections, the entity is deleted between the two intersection points. 2D Polylines are trimmed at their center line.



Drawing: TRIM.DWG

See previous page for command details

User Comments

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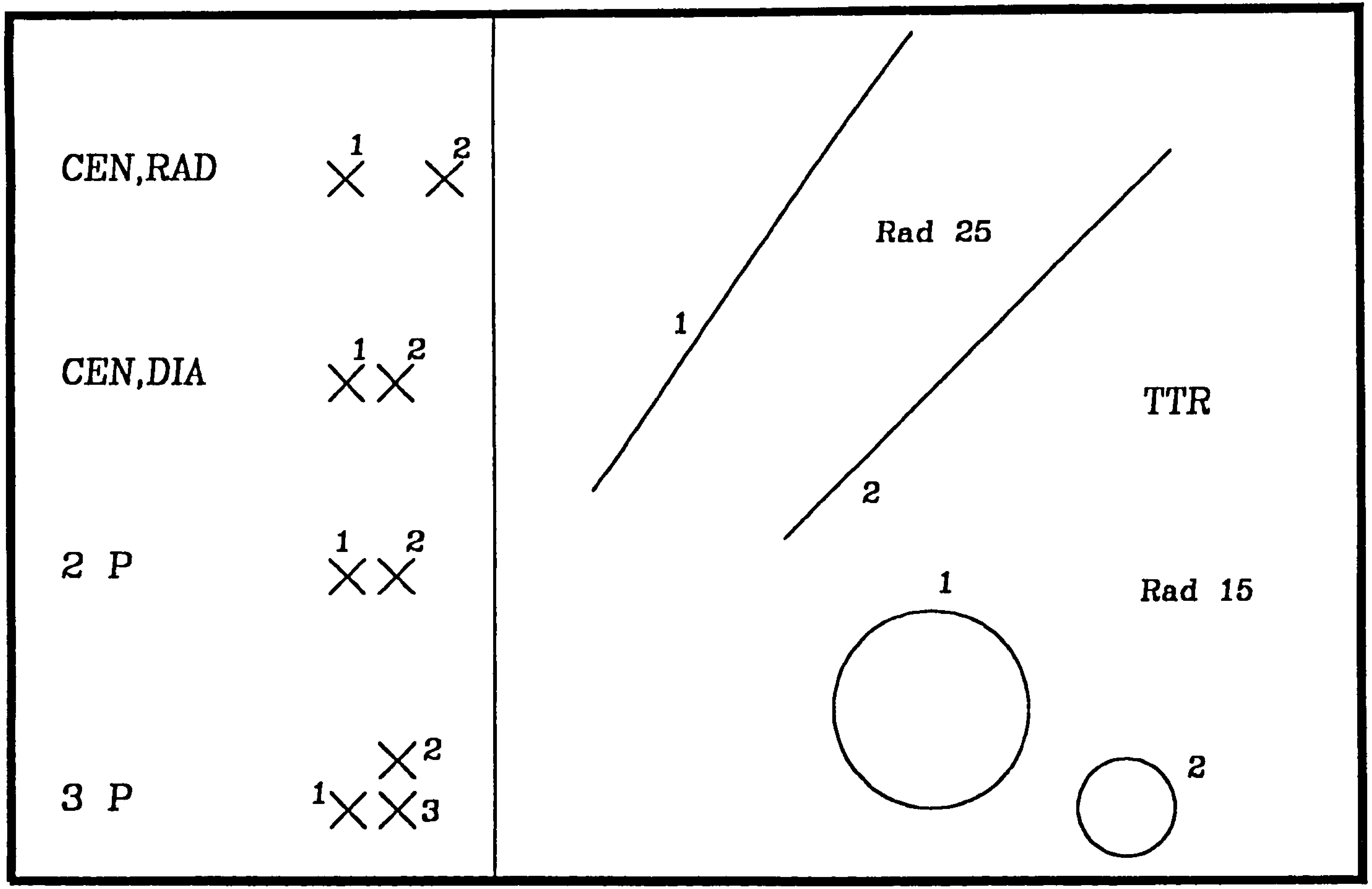
Circles.



Drawing: CIRCLES.DWG

Center, Radius	Draws a circle based on center point and radius.
Center, Diameter	Draws a circle based on center point and diameter.
2 Point	Draws a circle based on 2 endpoints of diameter.
3 Point	Draws a circle based on 3 points on the circumference.
Tangent, Tangent, Rad	Draws a circle based on the radius and two lines the circle is tangent to.

User Comments

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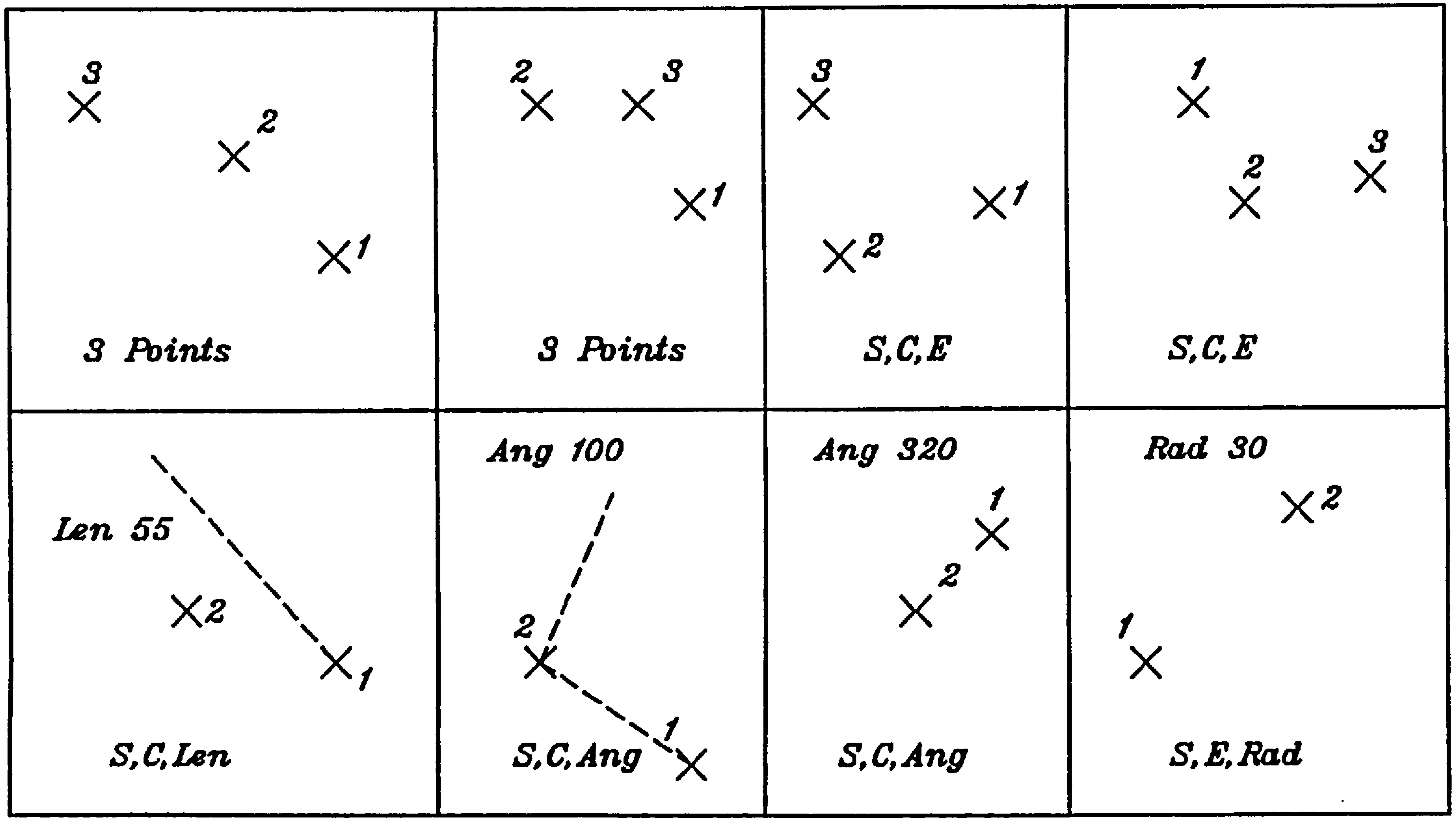
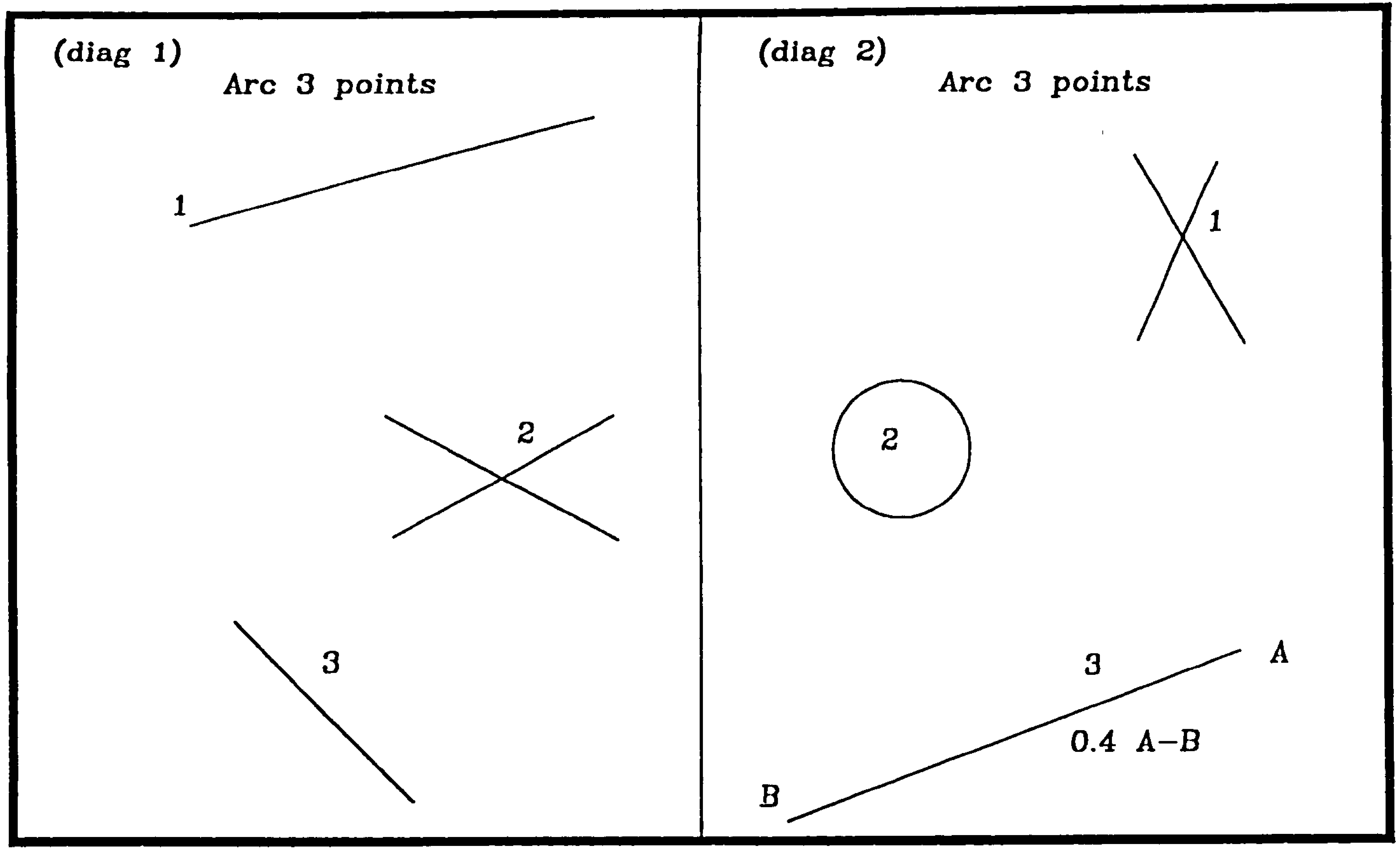


Drawing: ARC.DWG

3 Point	Arc based on 3 points.
Start, Center, End	Arc based on a start, center, and endpoint.
Start, Center, Angle	Arc based on a start point, center point, spanning an angle.
Start, Center, Length	Arc based on a start point, center point, and length of chord.
Start, End, Angle	Arc based on start point, endpoint, and specified angle.
Start, End, Radius	Arc based on a start point, endpoint, and radius.
Start, End, Direction	Arc based on a start point, endpoint, and direction from start point.
Center, Start, End	Arc based on a start point, center point, and endpoint.
Center, Start, Angle	Arc based on a center point, start point, and angle.
Center, Start, Length	Arc based on a center point, start point, and length of a chord.

User Comments



User Comments

Qn 1 determine length A–B

Qn 2 determine area of circle (diag 2)

Drawing: ATTACH.DWG

Center	Snaps to center of arc or circle.	Node	Snaps to node (point).
Endpoint	Snaps to closest endpoint of arc or line; corner of Trace/Solid/3D Face.	Perpendicular	Snaps perpendicular to arc, line, or circle .
Insert	Snaps to insertion point of Text/Block/Shape/Attribute.	Quadrant	Snaps to quadrant point of arc or circle.
Intersection	Snaps to intersection of line, arc, or circle.	Tangent	Snap to tangent of arc or circle.
Midpoint	Snaps to midpoint of arc or line.		
Nearest	Snaps to nearest point of arc, circle, line, or point.		

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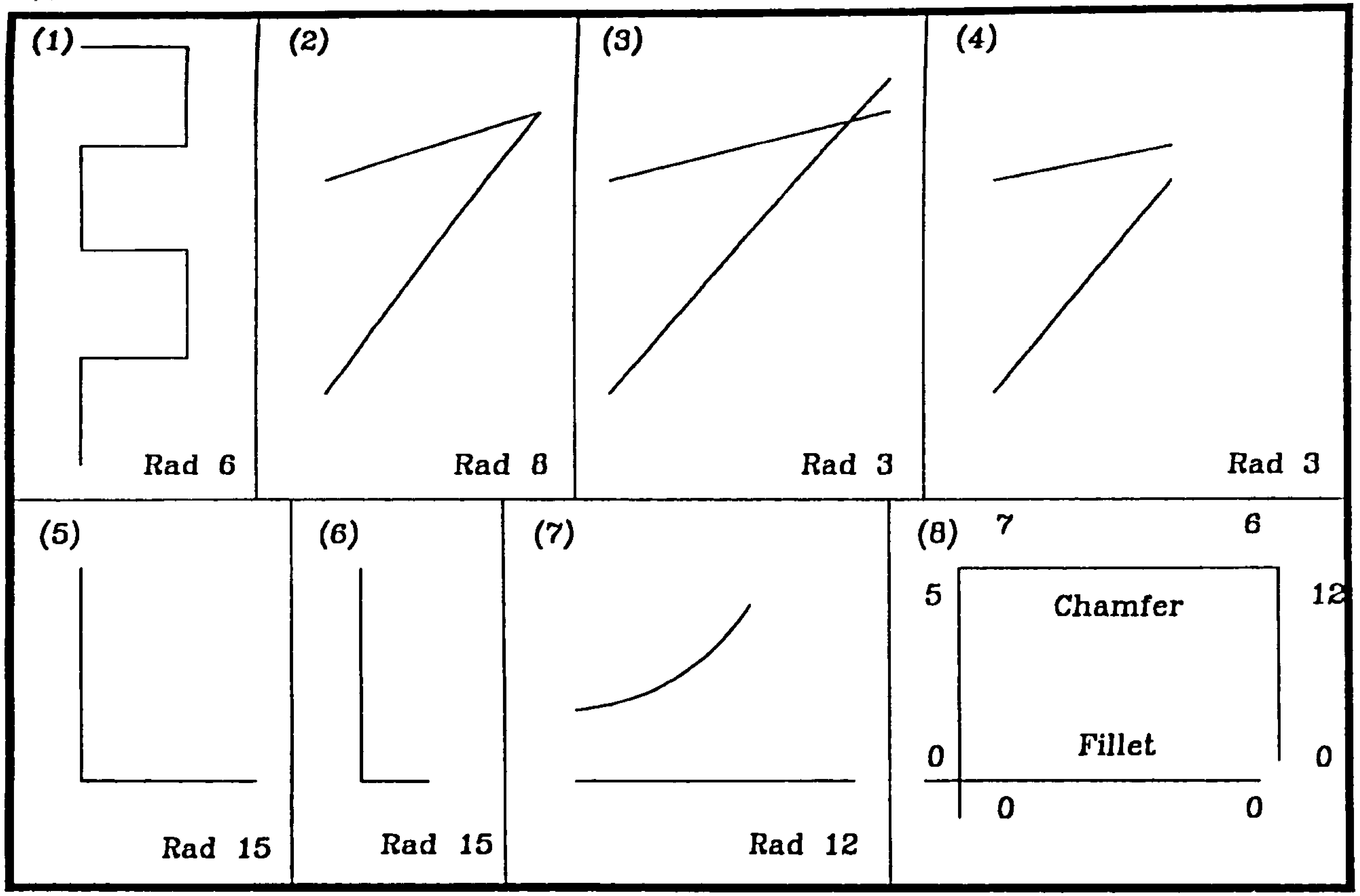
Fillets and Chamfers.



Drawing: FILLETS.DWG

User Comments

Format: FILLET
Polyline/Radius/<Select first object>:
Enter P or R or Select two entities to fillet.

Options

Polyline — Fillets an entire Polyline, or those segments to which the current radius can apply.
Radius — Sets the fillet radius for subsequent

Note: If you want to reset the radius before filleting, enter R and a value for the new radius. Then press (to reissue the FILLET command), and proceed to select the Polyline or two entities.

Format: CHAMFER
Polyline/Distances/<Select first line>:

Options

P — Chamfers entire Polyline.
D — Sets chamfer distances.

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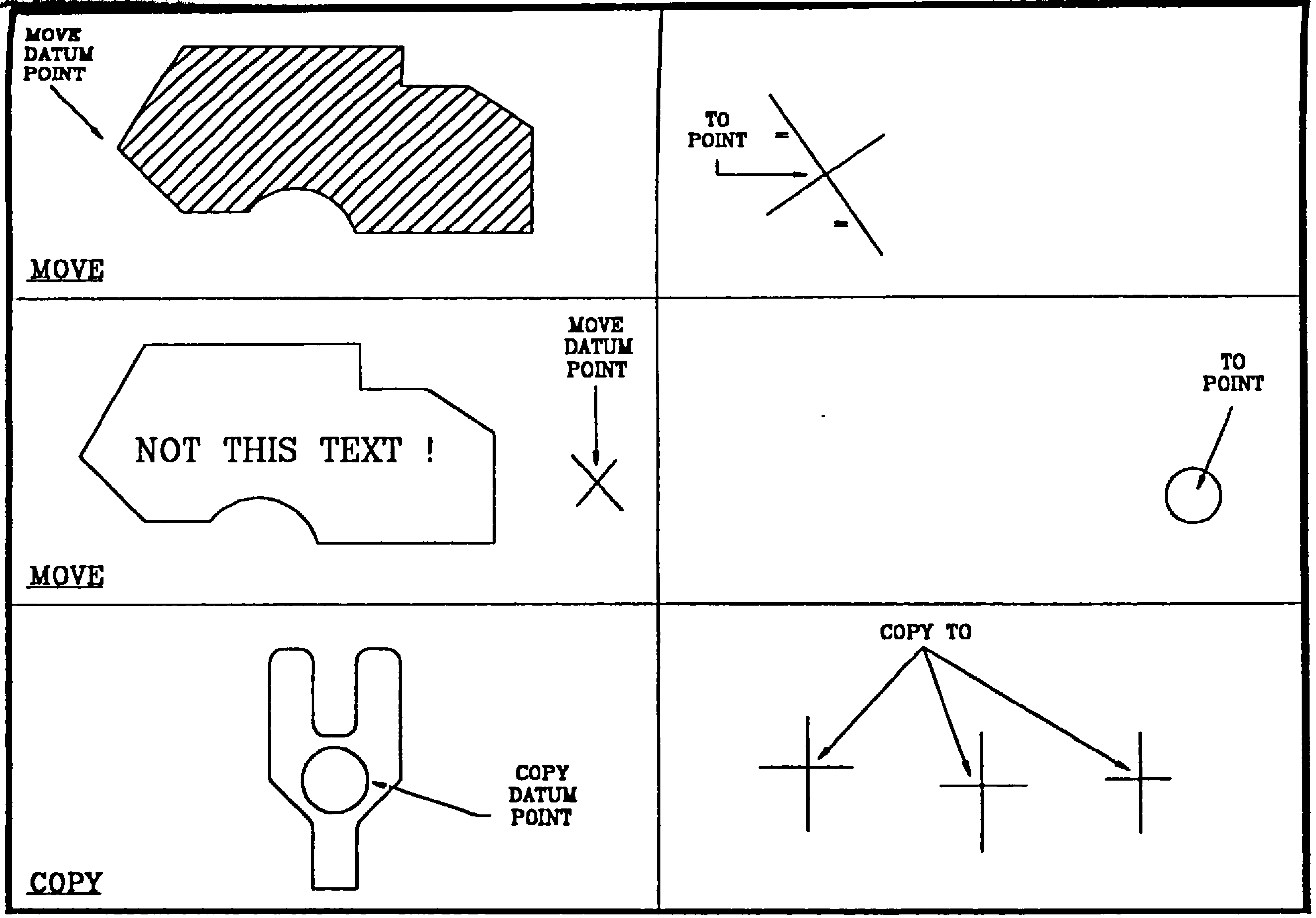

User Comments

Drawing: MOVE.DWG

The MOVE command is used to move one or more existing drawing entities from one location in the drawing to another.

Format: MOVE

Select objects:

Base point or displacement: Select a point or enter a displacement vector.

Second point of displacement: Select a point.

Use any entity selection method to select the objects to move. Then enter an X,Y,Z displacement vector, or specify two points to indicate how far the objects are to be moved.If you designate a base point, the selected object(s) are dynamically dragged to their new location.All forms of point entry are valid at the Base point or displacement: prompt. Entering a distance and angle moves the selected object(s) relative to the current UCS origin.

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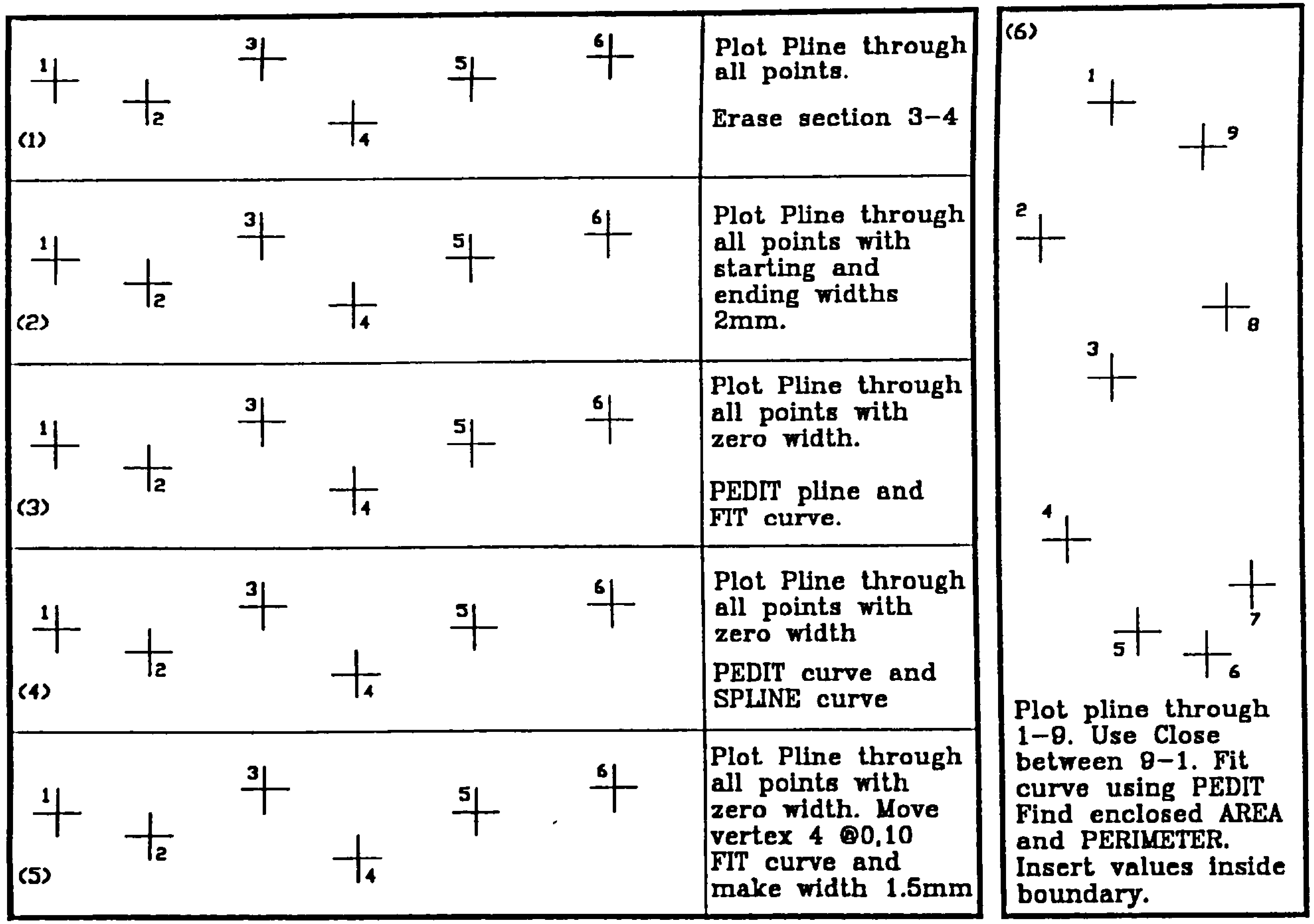

User Comments

Drawing: PLINE.DWG

The PLINE command draws Polylines, a connected sequence of line and arc segments treated as a single entity.

Format: PLINE

From point: Enter a point.

Arc/Close/Halfwidth/Length/Undo/Width/<Endpoint of line>: Enter a point or Select among options.

Note: PLINE defaults to Line Mode, drawing straight line segments, unless you select the Arc option, switching the command to Arc Mode.

To alter an existing Polyline, use the PEDIT command

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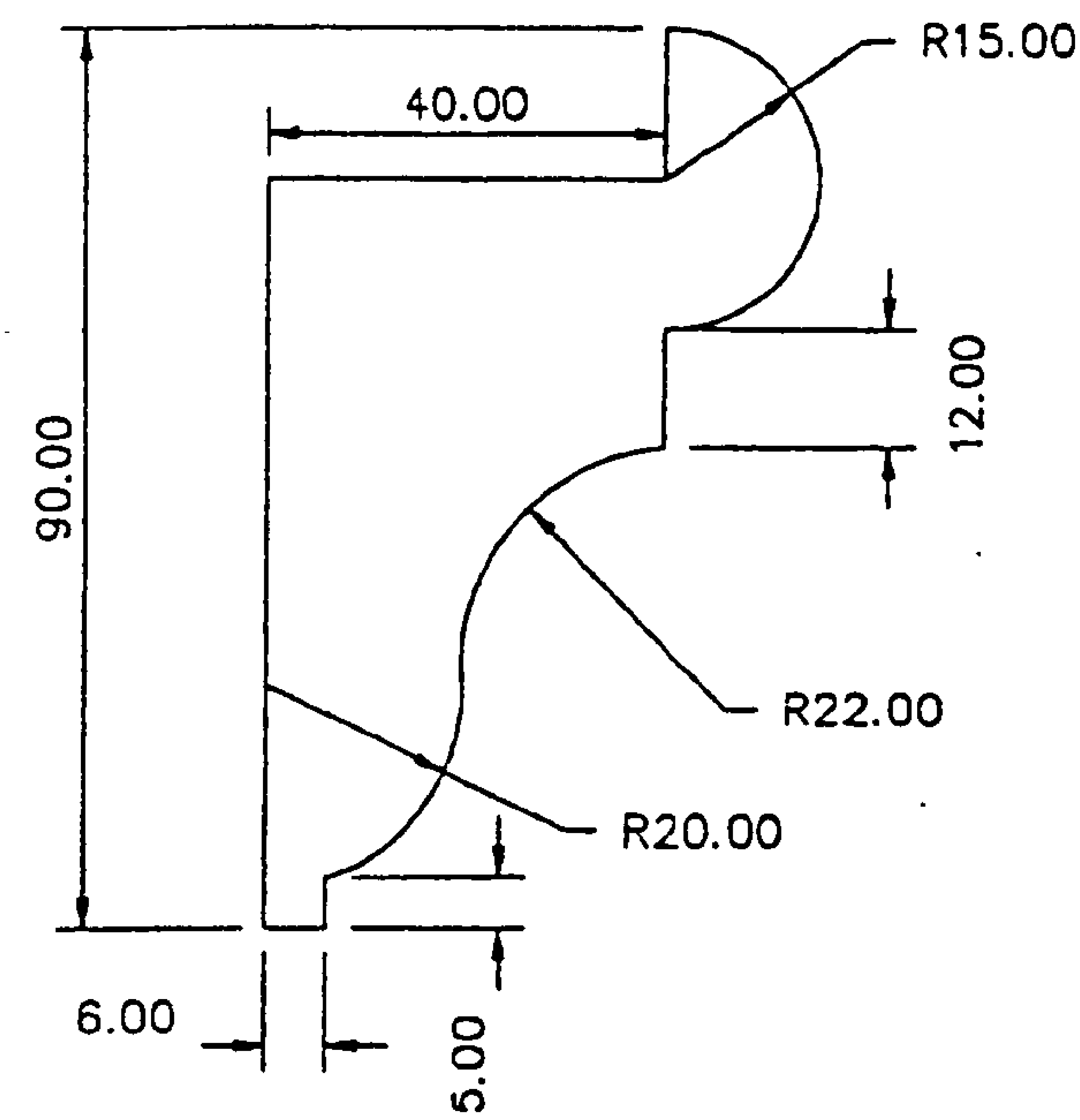
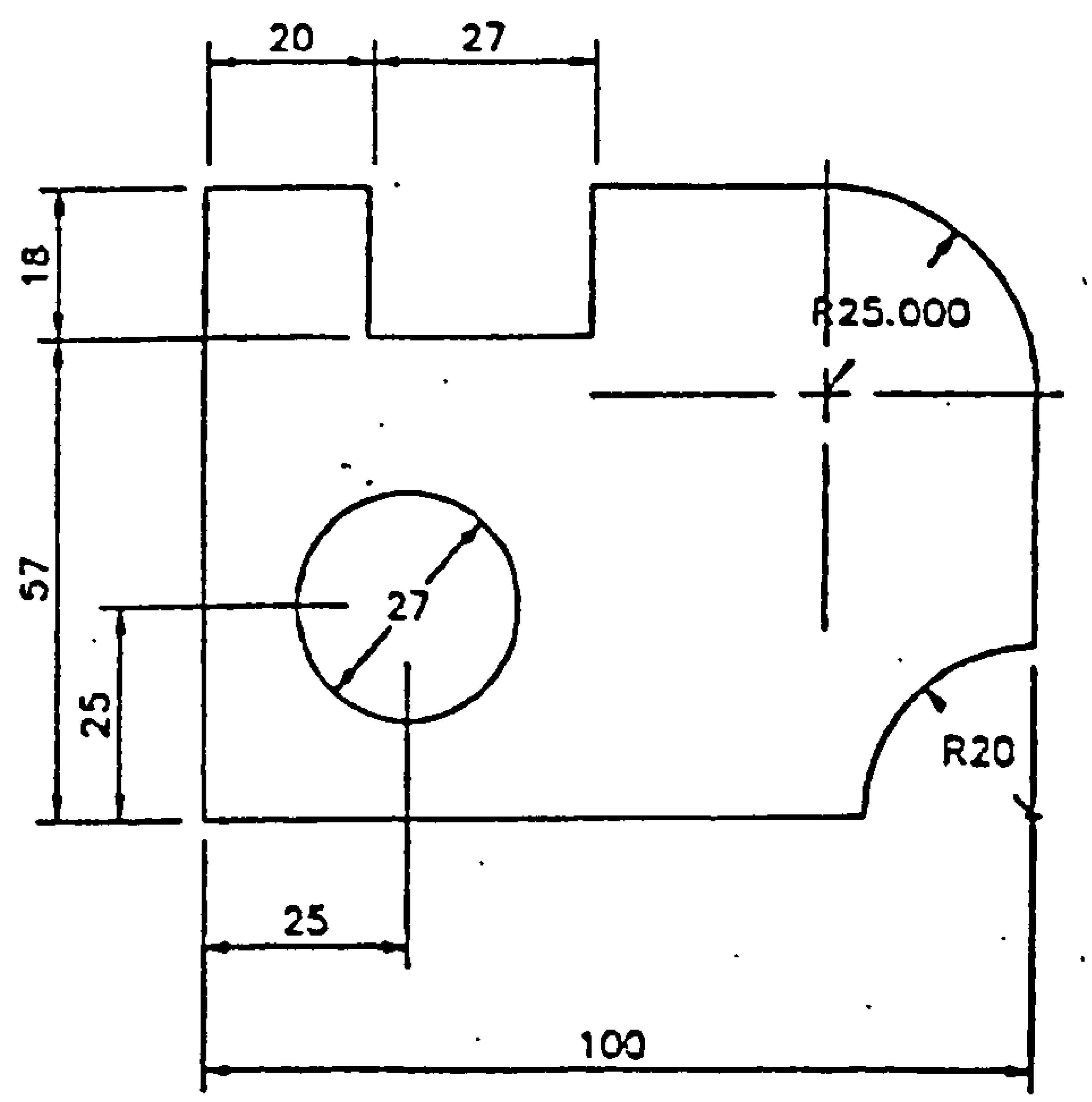
Additional Drawing Exercise

Extra 1



Extra 2



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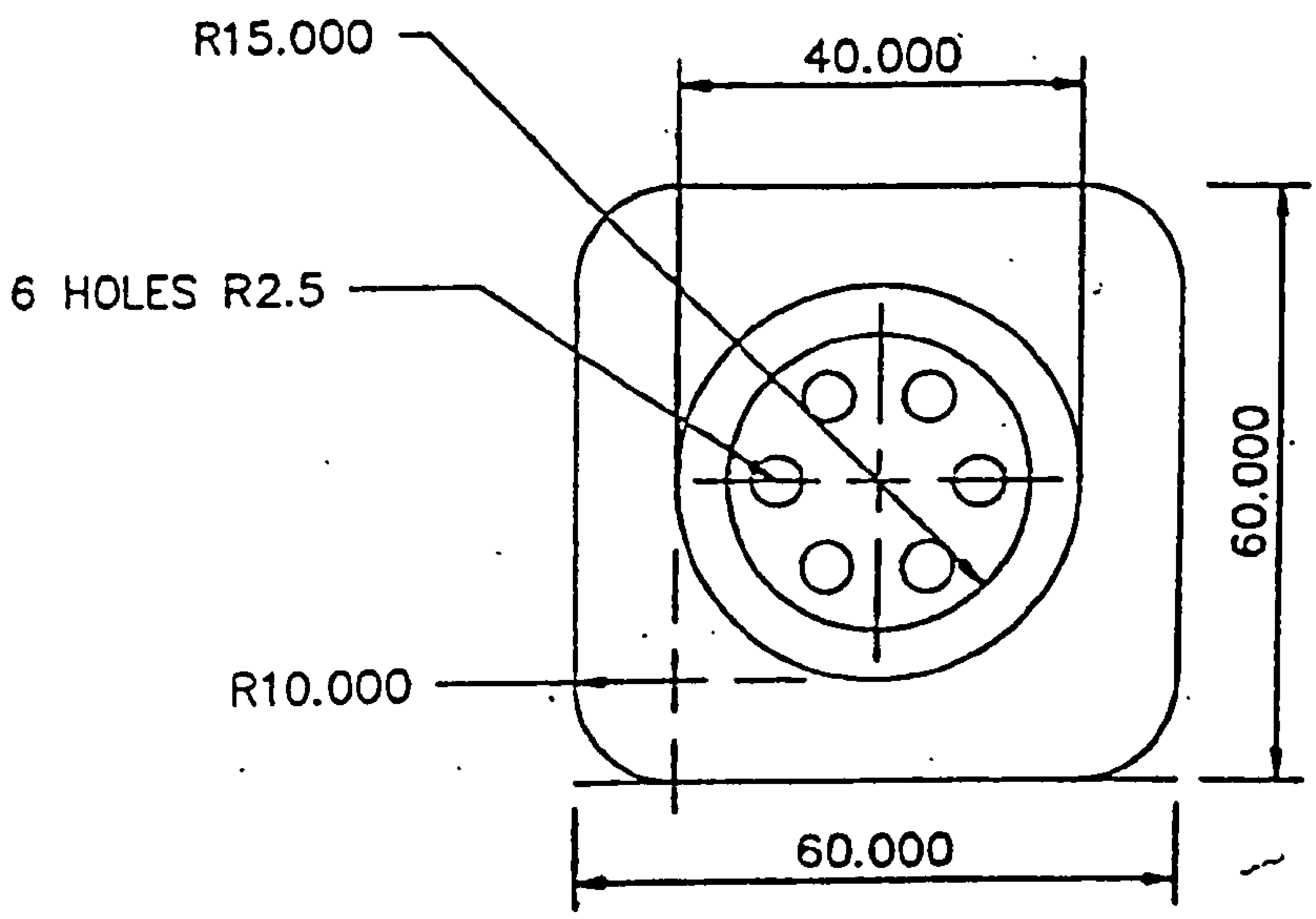
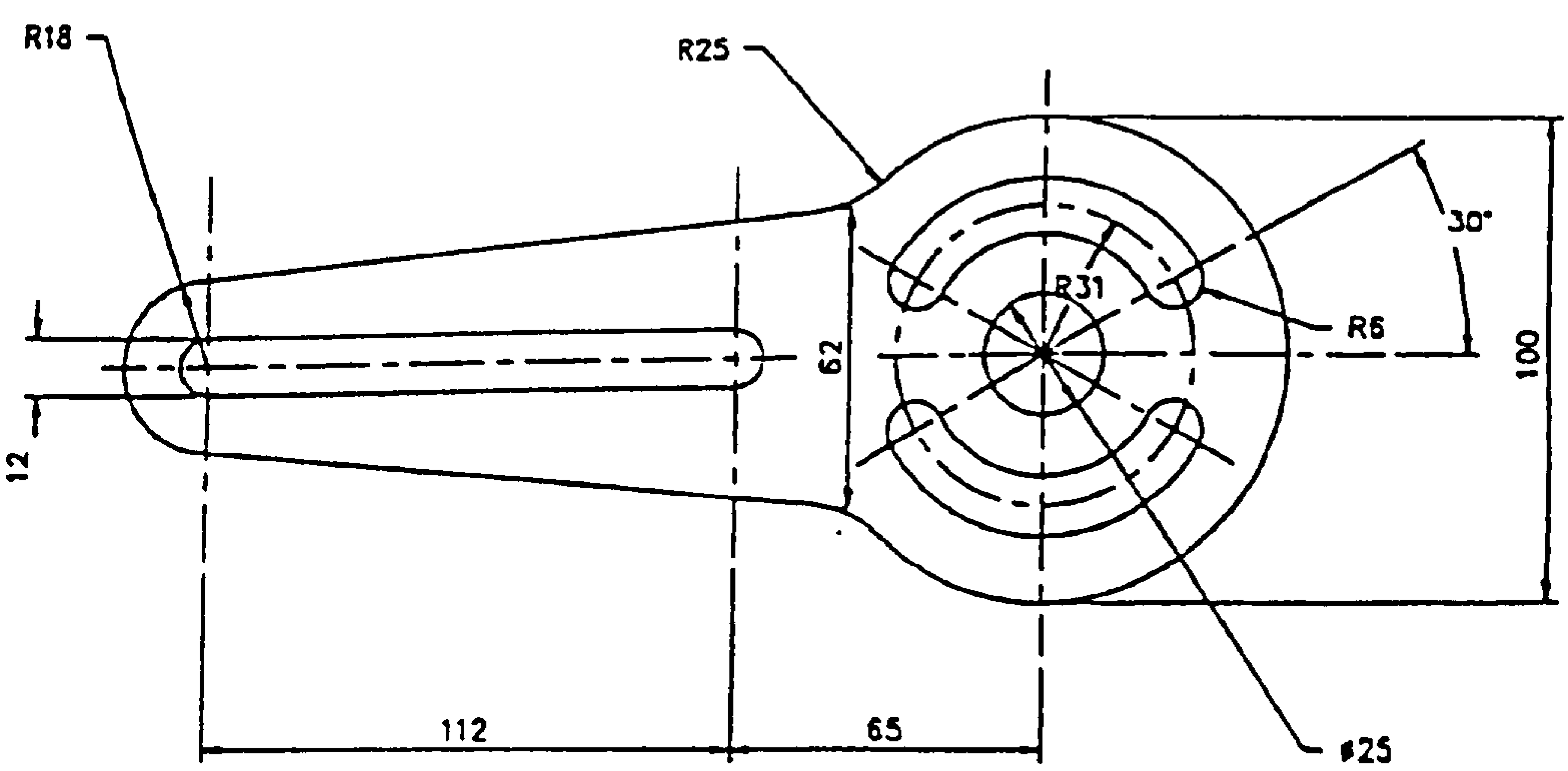
Additional Drawing Exercise

Extra 3.

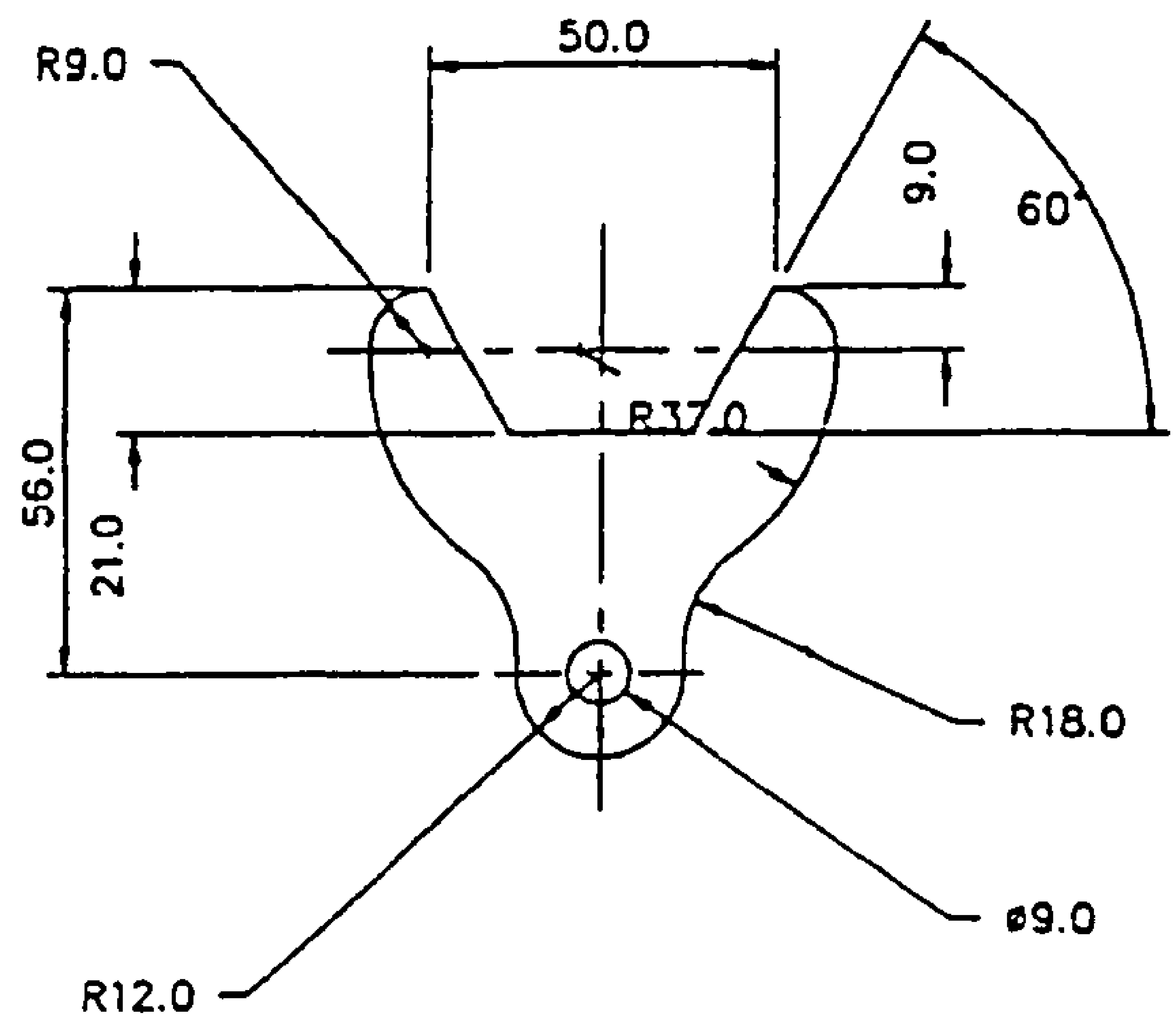


Extra 4.

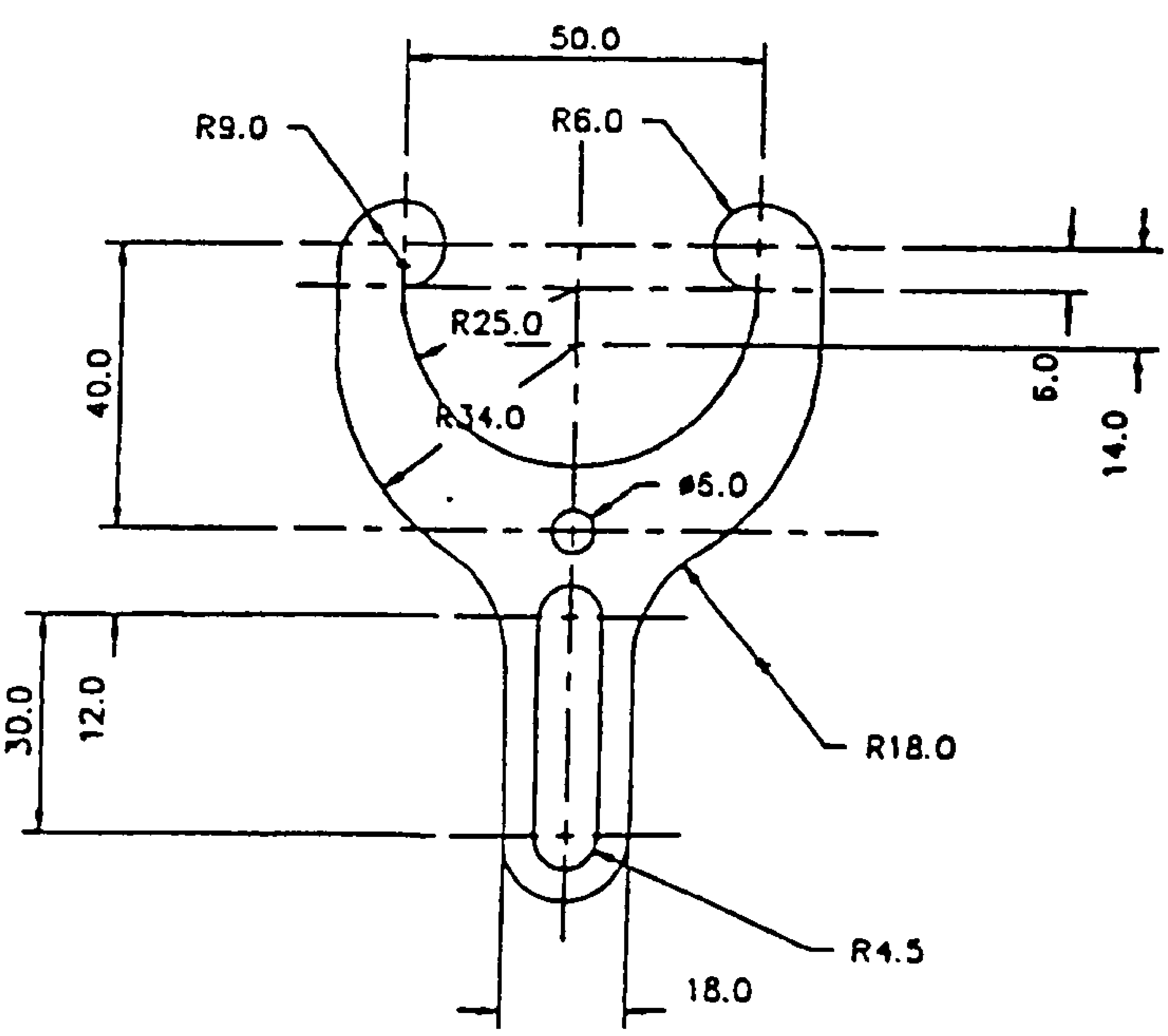


Additional Drawing Exercise

Extra 5.



Extra 6.



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Broadnet Engineering CAD Evaluation Questionnaire

PLEASE MAKE YOUR SELECTION WITH A HORIZONTAL LINE IN THE APPROPRIATE BOX LIKE ☐

Name: ☐

Course: ☐ Year: ☐ Date: ☐

Please rate each of the items below by marking one box only for each item,

Learning Experience

	Totally Agree 5	Agree 4	Neutral 3	Disagree 2	Totally Disagree 1
The package allows me to work at my own pace when studying the module	☐	☐	☐	☐	☐
The package is relevant to my needs for learning CAD	☐	☐	☐	☐	☐
The package gives useful guidelines for using CAD	☐	☐	☐	☐	☐
The package gives me flexibility to study at anytime	☐	☐	☐	☐	☐
The package would encourage me to study alone more	☐	☐	☐	☐	☐
The package gives me control over my learning	☐	☐	☐	☐	☐

Using the package

	Totally Agree 5	Agree 4	Neutral 3	Disagree 2	Totally Disagree 1
The package is useful	☐	☐	☐	☐	☐
The instructions provided with the package make it easy to use	☐	☐	☐	☐	☐
The package is enjoyable	☐	☐	☐	☐	☐
The content material / activities contained in the package are too simple	☐	☐	☐	☐	☐
The package is interesting	☐	☐	☐	☐	☐
The package is motivating	☐	☐	☐	☐	☐

CAD Skills

	Totally Agree 5	Agree 4	Neutral 3	Disagree 2	Totally Disagree 1
The package introduces CAD in a logical manner	☐	☐	☐	☐	☐
The package will improve my 2D CAD skills	☐	☐	☐	☐	☐
The package could be used without any prior CAD knowledge	☐	☐	☐	☐	☐
I prefer using the package to Lecture and Tutorial instruction on CAD	☐	☐	☐	☐	☐

Performance

	Totally Agree 5	Agree 4	Neutral 3	Disagree 2	Totally Disagree 1
Performance of the computer was adequate	☐	☐	☐	☐	☐
Performance of computer was too slow	☐	☐	☐	☐	☐
The computer monitor was adequate	☐	☐	☐	☐	☐
The computer monitor was too small	☐	☐	☐	☐	☐
The software ran with no problems	☐	☐	☐	☐	☐
I would have preferred the software downloaded from a floppy disc format	☐	☐	☐	☐	☐
I would have preferred the software in CD format	☐	☐	☐	☐	☐

continued overleaf

Any other comments or observations:-

Appendix IV

Company survey on recruitment criteria for Design Engineers and Product Designers

phd2\cosurvey1

As a potential officer recruiting designers for your company would you please complete the questionnaire on the basis of skills you feel are required by a newly qualified product designer. The responses will assist in research towards modifying design modules and highlight any specific shortfalls in the design curriculum for undergraduate courses in Product Design.

Company Name:---

Company Product:--

Age group preferred for post--

1. Educational background

1. Minimum Qualification for post:- BTEC ☐, ONC ☐, HNC ☐, HND ☐, BSc ☐, MSc ☐, PhD ☐

2. What study area is preferred by the company ? i.e. Product design, Electrical, Electronic, Mechanical, Manufacturing, Automotive etc.------------------------------

3. If an applicant has higher qualifications i.e. PhD would this put the company off ? YES☐ NO☐

4. Is graduate member of a Professional body important ? YES☐ NO☐

5. If YES which professional body is preferred ?--

6. Is Chartered Engineer status important once working for the company? YES☐ NO☐

7. If YES which professional body is preferred ?---

2. Work Experience

8. Is previous work experience essential ? YES☐ NO☐

9. If YES minimal number of years--------------------------

10. Is the area of work experience important ? YES☐ NO☐

11. If YES what area of work experience is most appropriate for the company?---

12. Is it important to have continuing professional development for staff once in the company to update their skills ? YES☐ NO☐

Designers Attributes and Qualities required for position

Please highlight the level of proficiency required in the following skills

3. Manual Drawing board ability and communication skills

	None	Basic	Competent	Good	Very Good
13. Produce Design Sketches / diagrams	☐	☐	☐	☐	☐
14.Read and interpret engineering drawings	☐	☐	☐	☐	☐
15. Produce part drawings	☐	☐	☐	☐	☐
16. Produce detail drawings	☐	☐	☐	☐	☐
17. Think in 3D	☐	☐	☐	☐	☐
18. Rendering skills using marker pens	☐	☐	☐	☐	☐
19. Produce a Physical model of a product in foam , wood etc.	☐	☐	☐	☐	☐
20. Produce hand written reports	☐	☐	☐	☐	☐

4. Use of Computers in Design

	None	Basic	Competent	Good	Very Good
21. Operate a CAD system for 2D drawing	☐	☐	☐	☐	☐
22. Operate a CAD system for 3D modelling	☐	☐	☐	☐	☐
23. Operate a CAD system for surface modelling	☐	☐	☐	☐	☐
24. Be able to use a computer for word processing reports, bar charts, pie charts etc.	☐	☐	☐	☐	☐

5. Analysis of Design

	None	Basic	Competent	Good	Very Good
25. Produce calculations for mass, volume bending moments and 2nd moment of area etc.	☐	☐	☐	☐	☐
26.Carry out stress analysis calculations on a component or Product	☐	☐	☐	☐	☐
27.Carry out Finite element Analysis on a component or Product	☐	☐	☐	☐	☐
28. Use ergonomics in the design process	☐	☐	☐	☐	☐

6. Business	None	Basic	Competent	Good	Very Good
29. Foreign Language requirement	☐	☐	☐	☐	☐
30. Preferred Foreign Language if applicable ----------------------------------					
31. Deal with clients	☐	☐	☐	☐	☐
32. Marketing	☐	☐	☐	☐	☐
33. Advertising	☐	☐	☐	☐	☐
34. Costing	☐	☐	☐	☐	☐
35. Appreciation of the role of other departments within the company	☐	☐	☐	☐	☐
36. Be able to plan a job	☐	☐	☐	☐	☐
37. Work as a member in a Design Team	☐	☐	☐	☐	☐
7. Manufacturing methods					
38. Knowledge of general processes:- casting, forging, presswork , welding etc.	☐	☐	☐	☐	☐
39. Knowledge of material properties for steels and other metals .	☐	☐	☐	☐	☐
40. Knowledge of material properties for plastics .	☐	☐	☐	☐	☐
41. Knowledge of component testing such as Tensile, Impact, Hardness etc.	☐	☐	☐	☐	☐
42. Computer Aided Manufacture (CAM)	☐	☐	☐	☐	☐
43. Robotics and material handling.	☐	☐	☐	☐	☐
44. An understanding of Electrical / Electronic systems	☐	☐	☐	☐	☐
45.Understanding of Pneumatics/Hydraulics	☐	☐	☐	☐	☐
46. Design for manufacture	☐	☐	☐	☐	☐
47. Design for assembly	☐	☐	☐	☐	☐

48. Knowledge of Stereolithography and Rapid Prototyping ☐ ☐ ☐ ☐ ☐

8. What skills do you feel new designers are lacking ?

---

9. Any other comments

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phd2\comp-cot.xls	QUESTION NO	1	2	3	4	5	6	7	8
Company Product and Responses	Age Group								
1. Power tools and Electrical Appliances.	job dependant	8	7	3	1	1	0	0	2
2. Cars / 4*4 Vehicles.	<30	5	7	2	2	0	1	1	1
3. Flight Control Equipment.	25-35	4	1	2	1	2	1	2	1
4. Electrical Installation Equipment.	25-35	3	7	2	2	0	2	0	1
5. New Product Development / Product Design.	24-40	1	1	2	2	0	2	0	1
6. Nut and Fastener Tightening Tools.	25-40	4	4	2	2	0	2	0	1
7. Locks.	25-45	2	4	2	2	0	2	0	1
8. Bathroom Products.	23-28	5	1	2	2	0	2	0	2
9. Vans and Pressings.	28-50	3	6	2	2	0	1	0	1
10. Mechanical Design for the Automotive Industry.	20-23	3	4	2	2	0	2	0	2
11. Showers and Mixer Valves.	22-25	4	4	2	1	2	1	2	2
12. Mini Excavators.	23-35	5	4	1	2	0	2	0	1
13. Fire Resisting Diskette Cabinets.	30+	3	1	1	2	2	2	2	1
14. Speedometers and Tachometers.	25-50	4	1	1	2	0	2	0	1
15. Office Equipment.	20-50	3	7	2	2	0	2	0	2
16. Bus and Coach bodies.	30-	4	6	1	2	0	2	0	1
17. Products for Aerospace/Petrochemical Industies.	20-30	4	4	1	2	0	2	0	2
18. Domestic Products.									
Criteria for Count	**QUESTION NO**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0 = no response upto question 12									
Question 13 - 48 the following applies for count	**NUMBER OF**								
0 = NONE	**0**	0	0	0	0	13	1	13	0
1 = BASIC	**1**	1	5	5	3	1	4	1	11
2 = COMPETENT	**2**	1	0	11	14	3	12	3	6
3 = GOOD	**3**	5	0	1					
4 = VERY GOOD	**4**	6	6						
	5	3	0						
	6	0	2						
	7	0	4						
	8	1							

9	10	11	12	13	14	15	16	17	18	19	20	21	22
0	0	1	1	3	3	2	2	3	3	2	3	3	2
0	1	1	1	4	4	4	4	4	1	1	2	4	1
5	1	1	1	3	4	3	3	4	3	2	4	4	4
2	2	0	1	3	4	1	1	4	0	0	3	4	2
4	1	2	1	3	3	3	3	3	3	3	2	3	3
5	1	2	1	3	4	4	4	4	0	0	4	4	0
10	1	2	1	4	4	3	3	3	2	0	3	4	2
0	0	0	1	3	3	2	3	4	3	4	2	3	2
2	1	2	1	3	3	4	4	2	1	1	3	3	2
0	2	0	1	1	2	2	3	4	2	2	3	4	2
0	1	1	1	3	3	2	1	3	0	1	3	1	3
1	1	3	2	1	3	2	2	3	0	1	1	3	1
5	1	1	1	3	4	3	3	3	3	2	4	4	4
2	1	4	1	2	3	2	2	3	2	0	3	3	2
0	1	3	1	4	4	4	4	4	1	0	2	4	4
8	1	2	1	3	4	3	3	4	2	2	3	4	2
0	1	3	1	4	4	4	4	4	1	2	4	4	4

9	10	11	12	13	14	15	16	17	18	19	20	21	22
7	2	3	0	0	0	0	0	0	4	5	0	0	1
1	13	5	16	2	0	1	2	0	4	4	1	1	2
3	2	5	1	1	1	6	3	1	4	6	4	0	8
0		3		10	7	5	7	7	5	1	8	6	2
1		1		4	9	5	5	9	0	1	4	10	4
3													

ANALYSIS OF COMPANY RESPONSES TO QUESTIONAIRE. Page 2

23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	2	3	3	3	3	1	0	0	3	1	3	3	4
1	2	1	4	4	4	2	2	3	1	1	4	4	4
4	3	4	4	4	3	2	0	3	3	3	3	3	4
0	4	1	0	0	1	0	0	0	0	0	2	2	3
3	2	3	3	2	3	2	1	3	1	0	2	1	3
1	4	4	2	0	4	1	1	3	3	0	3	3	4
2	2	3	2	2	2	0	0	2	2	1	3	3	2
1	1	1	0	0	1	1	3	0	3	0	1	3	3
1	4	3	2	1	1	1	0	3	3	1	4	3	3
2	3	2	2	3	3	3	0	2	1	1	1	3	1
3	3	3	3	3	4	0	0	3	3	0	3	3	3
1	1	3	2	2	2	1	0	2	1	0	3	2	2
3	4	2	2	1	4	3	0	4	4	2	4	4	4
0	4	2	0	0	0	0	0	3	2	2	3	3	4
4	1	3	1	1	3	0	0	3	2	2	3	4	4
3	2	3	3	2	2	0	0	2	1	0	2	3	4
4	3	4	4	4	3	1	1	3	1	1	3	3	3

23	24	25	26	27	28	29	30	31	32	33	34	35	36
2	0	0	3	4	1	6	12	3	1	7	0	0	0
6	3	3	1	3	3	6	3	0	6	6	2	1	1
2	5	3	6	4	3	3	1	4	3	3	3	2	2
4	4	8	4	3	6	2	1	9	6	1	9	11	6
3	5	3	3	3	4	0	0	1	1	0	3	3	8

ANALYSIS OF COMPANY RESPONSES TO QUESTIONAIRE. Page 3

37	38	39	40	41	42	43	44	45	46	47	48
4	4	3	4	3	2	2	3	4	4	4	3
4	2	2	2	2	2	2	2	1	4	4	1
4	4	4	2	3	4	2	4	4	4	4	3
4	3	3	3	1	2	1	1	1	4	4	2
3	3	3	3	2	1	1	2	2	3	2	1
4	4	4	2	4	1	1	1	2	4	4	0
3	3	4	2	2	1	1	1	1	4	4	1
4	1	0	1	0	1	0	0	0	2	1	2
3	4	3	2	2	2	1	3	2	3	4	1
4	3	3	2	2	1	3	1	2	1	2	0
4	3	3	4	3	3	0	3	1	4	4	4
3	3	2	2	1	2	1	2	3	3	3	1
4	2	3	3	3	3	2	1	2	4	4	2
3	1	0	1	0	0	0	3	0	2	2	2
4	4	4	4	2	1	1	1	1	4	4	1
3	3	4	3	3	2	1	2	1	2	4	1
4	3	4	3	3	3	3	2	4	4	4	2
37	38	39	40	41	42	43	44	45	46	47	48
0	0	2	0	2	1	3	1	2	0	0	2
0	2	0	2	2	6	8	6	6	1	1	7
0	2	2	7	6	6	4	5	5	3	3	5
6	8	7	5	6	3	2	4	1	3	1	2
11	5	6	3	1	1	0	1	3	10	12	1

ANALYSIS OF COMPANY RESPONSES TO QUESTIONAIRE. Page 4

Appendix V

B Sc Computer Aided Product Design

(Industrial Design Option)

ar 1

ne er 1	***Product Design Studies 1*** ***CM1106***	Product Manufacturing Studies 1 MA1103	Computer Aided Engineering CM1108	Design Communication Studies CM1107
ne er 2	***Product Design Studies 2*** ***CM1101***	Fundamentals of Technology 2 CM1105	Fundamentals of Technology 1 CM1104	Graphics CM1109

a 2

ne er 1	***Design Principles*** ***DS2229***	Principles of CAD CM2201	Engineering Design ET2233	Design Analysis CM2205
ne er 2	***3D Realisation*** ***DS2228***	Graphical Modelling CM2203	Design Enterprise Studies CM2206	Design Practice CM2207

ea 3

ne er 1	Design Assurance CM3303	Project Planning DS3310	Design Information Systems CM3304	Design Competition CM3305
nester 2	Design Enterprise Project CM3306	Project DS3311	Project DS3311	Management of Design CM3302

B Sc Computer Aided Product Design
(CAD Option)

ear 1				
mester 1	***CAD Fundamentals*** ***CM1004***	Product Manufacturing Studies 1 MA1103	Computer Aided Communications CM1003	Product Design and Development CM1000
mester 2	***CAD Applications*** ***CM1001***	Fundamentals of Technology 2 CM1105	Fundamentals of Technology 1 CM1104	Graphics CM1109
ear 2				
mester 1	***Graphical Modelling*** ***CM2203***	Design Principles DS2229	Engineering Design ET2233	Design Analysis CM2205
nester 2	***Advanced Modelling*** ***CM2000***	3D Realisation DS2228	Design Enterprise Studies CM2206	Design Practice CM2207
ear 3				
nester 1	Design Assurance CM3303	Project Planning DS3310	Design Information Systems CM3304	Design Competition CM3305
nester 2	Design Enterprise Project CM3306	Project DS3311	Project DS3311	Management of Design CM3302

B Sc Computer Aided Product Design

(Consumer Electronics Option)

ar 1

nester 1	*Introductory Electronics* *EP1001*	Product Manufacturing Studies 1 MA1103	Computer Aided Engineering CM1108	Design Communication Studies CM1107
nester 2	*Sensors and Actuators* *EP1003*	Product Design and Development CM1000	Fundamentals of Technology 1 CM1104	Graphics CM1109

ar 2

nester 1	*Digital Devices* *EP2004*	Principles of CAD CM2201	Engineering Design ET2233	Design Analysis CM2205
nester 2	*Consumer Electronics* *EB2001*	Graphical Modelling CM2203	Design Enterprise Studies CM2206	Design Practice CM2207

ar 3

nester 1	Design Assurance CM3303	Project Planning DS3310	Design Information Systems CM3304	Design Competition CM3305
nester 2	Design Enterprise Project CM3306	Project DS3311	Project DS3311	Management of Design CM3302

B Sc Computer Aided Product Design

(Language Option)

ear 1

mester 1	*Language 1*	Product Manufacturing Studies 1 MA1103	Computer Aided Communications CM1002	Product Design and Development CM1000
mester 2	*Language 2*	Fundamentals of Technology 2 CM1105	Fundamentals of Technology 1 CM1104	Graphics CM1109

ear 2

emester 1	*Language 3*	Principles of CAD CM2201	Engineering Design ET2233	Design Analysis CM2205
emester 2	*Language 4*	Graphical Modelling CM2203	Design Enterprise Studies CM2206	Design Practice CM2207

ear 3

emester 1	Design Assurance CM3303	Project Planning DS3310	Design Information Systems CM3304	Design Competition CM3305
emester 2	Design Enterprise Project CM3306	Project DS3311	Project DS3311	Management of Design CM3302

B Sc Computer Aided Product Design
(Business Studies Option)

ear 1

emester 1	***Business Studies 1***	Product Manufacturing Studies 1 MA1103	Computer Aided Communications CM1002	Product Design and Development CM1000
emester 2	***Business Studies 2***	Fundamentals of Technology 2 CM1105	Fundamentals of Technology 1 CM1104	Graphics CM1109

ear 2

emester 1	***Business Studies 3***	Principles of CAD CM2201	Engineering Design ET2233	Design Analysis CM2205
emester 2	***Business Studies 4***	Graphical Modelling CM2203	Design Enterprise Studies CM2206	Design Practice CM2207

ear 3

emester 1	Design Assurance CM3303	Project Planning DS3310	Design Information Systems CM3304	Design Competition CM3305
emester 2	Design Enterprise Project CM3306	Project DS3311	Project DS3311	Management of Design CM3302

B Sc Computer Aided Product Design

(Business Enterprise Option)

ear 1

emester 1	***Business Organisation and Analysis BA1133***	Product Manufacturing Studies 1 MA1103	Computer Aided Communications CM1003	Product Design and Development CM1000
emester 2	***Enterprise at work BA2235***	Fundamentals of Technology 2 CM1105	Fundamentals of Technology 1 CM1104	Graphics CM1109

ear 2

emester 1	***Management of Operations IT2207***	Principles of CAD CM2201	Engineering Design ET2233	Design Analysis CM2205
emester 2	***The Developing Business BA2003***	Graphical Modelling CM2203	Design Enterprise Studies CM2206	Design Practice CM2207

ear 3

emester 1	Design Assurance CM3303	Project Planning DS3310	Design Information Systems CM3304	Design Competition CM3305
emester 2	Design Enterprise Project CM3306	Project DS3311	Project DS3311	Management of Design CM3302